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A methodology of investment appraisal for third-level airlines

Volume I

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To Mom

"There are no hard decisions, just insufficient facts.
When you have the facts, the decisions come easy."

George M. Humphrey
Former Secretary of the U.S. Treasury

SUMMARY

Third-level airlines are approached as a financial system composed of models of travel demand and cost. The models are formulated by multiple regression, subjective probability distributions, and weighted random-walk techniques because these techniques result in probability distributions which may be input into a risk analysis program. The risk analysis program is used to investigate the cash required to start, by the method of "Optimum Coverage", an example third-level airline in Oregon. The risk analysis program is also used to analyze the airline as an investment and to determine the proper method of finance.

The airline required from $4.2 million to $6.1 million dollars to begin operations and had expected internal rates of return from 25% to 62% depending on the method of finance.

The analysis shows that the airline performs best as a tax shelter and that in every instance, with an average weighted cost of capital exceeding 2.0%, the airline should exchange tax benefits (either as a tax shelter or by leasing aircraft) for more favorable financial terms.

New travel demand forecasting methods investigated included a method for combining the flight frequency, the time of desired departures, and the difference between mode travel times into a single independent variable; and a method for combining population, income, and the distribution of personal income into a single independent variable. Hence, a single independent variable may account quantitatively for the effects of several variables when only a small data base is available.

The short-haul nature of the third-level airline routes were found to make traffic more sensitive to quality-of-service variables than price, and the costs of third-level airlines were best determined by the revenue-passenger-miles they produced.

The reserve aircraft problem and the service levels of engines and avionics are determined using the concept of affordable risk. Rate Per Hour Contracts are beneficial for the small operator for avionics, but they are beneficial for engines only if there is also an exchange agreement.

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NOTATION

ADF	Automatic Direction Finder
AR	Affordable Risk
ARINC	Aeronautical Radio Incorporated
ATC	Air Traffic Control
BT	Block Time
C	Fixed Costs of Ownership
CAB	Civil Aeronautics Board
CAS	Calibrated Airspeed
CF_t	After-Tax Cashflow in Period "t", But Before Interest
Comm	Communications Radio
Con	Contribution
DME	Distance Measuring Equipment
DOC	Direct Operating Costs
DP	Dummy Variable for Portland
DPFI	Domestic Passenger Fare Investigation
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FBO	Fixed-Base Operator
FCC	Federal Communication Commission
FS	Fraction of Traffic Southbound
GS	Glideslope
GTOW	Gross Take-Off Weight (pounds)
hr	Hour(s)
HW	Headwind
i	Cost of Capital or Discount Rate
IFR	Instrument Flight Rules
IOC	Indirect Operating Costs
IRR	Internal-Rate-of-Return
IRS	Internal Revenue Service
ISA	International Standard Atmosphere
ITC	Investment Tax Credit
K( )	Coefficient or Calibration Constant of Regression
LOC	Localizer
MCTR	Mean-Cost-To-Repair
MKR	Marker Beacon Receiver
mph	Miles per Hour (statute)
MTBF	Mean-Time-Between-Failure
MTBMA	Mean-Time-Between-Maintenance-Action
MTBO	Mean-Time-Between-Overhaul
MTBR	Mean-Time-Between-Removal
MTBUR	Mean-Time-Between-Unscheduled-Removal
MTTR	Mean-Time-To-Repair
Nav	Navigation Radio (VOR)
NPV	Net-Present-Value
O&D	Origin & Destination Traffic
P( )	Probability of ( ) or Probability Density Function of ( )
PIM	Product of the Income-Weighted Taxable Income Distributions Multiplied by the Population Products
R	Revenue
RPHC	Rate Per Hour Contract
RPM	Revenue-Passenger-Miles
S	Opportunity Costs
SIC	Standard Industrial Classification
SPD	Subjective Probability Distribution
sm	Statute Mile(s)

NOTATION
(concl'd)

TBO	Time-Between-Overhaul
TSO	Technical Standard Order
U	Daily Utilization of Aircraft (hours)
U_1	Annual Utilization of Aircraft (hours)
V	Variable Costs
Vs	Short-term Variable (Escapable) Costs
VA	Volt-Amperes
VFR	Visual Flight Rules
VHF	Very High Frequency
VOR	Very High Frequency Omni-Range Navigation
WAT	Weight-Altitude-Temperature
WPIIC	Wholesale Price Index of Industrial Commodities
δ	Change Per Foot of Altitude
λ	Failure Rate
μ	Arithmetic Mean
σ	Standard Deviation
ΔT	Perceived Difference in Travel Time Between Travel Modes
^{o}C	Degrees Centigrade

1. INTRODUCTION

1.1 Why Study Third-Level (or Commuter) Airlines

Third-level airlines have been studied before, but nearly all the studies were government funded. This resulted in the objective being the provision of service to marginal points through a route cross-subsidy scheme rather than the development of a profitable airline. A consequence of this is that more data and analyses are available on the least successful airlines and routes than on the most successful airlines and routes. This study is only concerned with successful, profitable airlines and routes.

Third-level airlines represent U. S. airlines in a free market system. There is no subsidy and a minimum of economic regulation. All U. S. airlines over the next few years are expected to be operating in a less restrictive economic environment and the study of third-level airlines may indicate where such an environment will lead.*

1.2 Study Objective

The purpose of this thesis is to develop a method of financial planning for third-level (commuter) airlines during their institution and operation. The object of the financial planning is the analysis and subsequent reduction of risk to promote the stable and orderly growth of the airline in concert with its potential investment community.

Oregon is used as an example of an area requiring third-level service because in recent years its local trading centers have been abandoned by U. S. certificated carriers. Although Oregon was chosen as the example, an important criterion of this study was that the data and methods have universal applicability.

1.3 Background

The present development of the U. S. air transportation system can be traced to the Civil Aeronautics Act of 1938. This act has not allowed entry into the trunk airline ranks (the first-level of service) since it was passed at the urging of the nineteen airlines promoting its enactment.

In 1944 the Civil Aeronautics Board (CAB) announced that it was initiating an "experiment" with a second level of certificated air service, termed "local service air carriers", at points where traffic potential had not encouraged service by the trunk carrriers, pursuant to the will of the Congress that no community of significant size should do without the benefits of public air service. Both first and second levels of service received certificates of "public convenience and necessity."[1] The certificates guaranteed freedom from competition in markets where it could be financially damaging and provided "fair and reasonable rates of compensation for the transport of mail by aircraft" in such a manner as to "maintain and continue the develop-

* Progressive deregulation of U.S. civil aviation was begun on October 24, 1978 by the Federal Aviation Act of 1978.

ment of air transportation to the extent and of the character and quality required for the commerce of the United States, the Postal Service, and the National Defense."[2]

From the early 1950s to mid-1960s, the CAB pursued a policy of route strengthening to promote internal subsidies in the hope of eliminating external subsidies. Originally local service carriers were required to service every station on a route every time they flew the route. The number of stops required between air service hubs effectively kept local service carriers from competing with trunks. The route strengthening policy included by-pass routes which authorized minimal service (two departures per day) to intervening points between some hubs.[1]

The resulting denser, long-haul routes made larger, faster aircraft more attractive economically and a virtual necessity for a local service carrier attempting to compete on a route with a trunk carrier. In 1966 the CAB approved, in principle, Central Airline's request to offer jet service (DC-9s) on their by-pass routes. (This was not as much an authorization as it was an acknowledgement by the CAB that they would not attempt to prohibit subsidy for jet equipment; the Federal Aviation Act of 1958 did not, nor did previous acts, give the CAB the power to specify equipment.) Jet aircraft often made the intervening points between hubs unprofitable. As a result, the local service strategy became to provide excellent service at prime times to profitable stations and routes in order to maximize revenue, to provide minimum service at off-peak times to unprofitable stations or routes to minimize cost, and to meet the conditions of their certificate to ensure subsidy. Because of the CAB's inability to regulate aircraft size, the route strengthening program has resulted in more subsidy, rather than less, for unprofitable stations or routes that now receive jet service.

The unprofitable stations are subject to the CAB's "use-it-or-lose-it" policy whereby a station, even when offered only two ill-timed flights per day, can be dropped if it fails to board at least five passengers per day.[1] In addition, local service carriers no longer want to serve smaller markets because:

1. The subsidy is often less than promised.

2. The airline is blamed for both the magnitude of the subsidy and the disappointments of the public.

3. The subsidy can be dropped and the airline required to continue service under its certificate of public convenience and necessity, e.g., trunks no longer receive subsidy regardless of market size.

4. Aircraft that should be profitable in the market are not because of union agreements based on higher fleet productivity.

5. High reliability is required to make the service viable and avoid public image problems because of short stage-lengths and competing modes. Yet, in a strain on maintenance resources, the airline feels compelled to fix the least productive aircraft last.

Since 1966 because of economics, politics, image problems, and a desire to move to trunk-line status, local service carriers have been abandoning low-density, short-haul markets at the rate of approximately 14 stations per year (2% of the total markets). These are the very markets they were specifically created to serve only twenty years earlier.[1] It is estimated that by 1979, at the current rate of abandonment, the remaining points will support the local service carrier all-jet fleet without subsidy.[3] This set the stage for third-level airlines.

1.3.1 Third-Level or Commuter Terminology

Since the beginning, the term commuter airline has been a misnomer because few passengers were commuters. The term third-level is used in this study because it accurately reflects what the small airlines produce, everything a larger carrier does, and the level on which they produce it, a level distinctly below either trunks or local service carriers. In 1977 the trunk carriers produced 90.7% of all revenue-passenger-miles, the local service carriers produced 8.7%, and the third-level carriers produced 0.6%.[4]

1.3.2 Economic Regulation of Third-level Airlines

The Civil Aeronautics Act of 1938, Regulation 400-1, exempted non-scheduled carriers from obtaining a certificate of public convenience and necessity. In its "Investigation of Nonscheduled Air Services" in 1944, the CAB concluded that the distinction between scheduled and nonscheduled was fundamental. A new class of "noncertificated irregular carrier" was created. Noncertificated irregular carriers were divided into "large irregular carriers" and "small irregular carriers" (below 10000 pounds Gross Take-Off Weight [GTOW]). In 1949 small carriers were redefined as those with a GTOW of 12500 pounds or less. In 1952 part 298 of the CAB Economic Regulations created air taxi operators, limited them to routes within the United States, restricted operations in territories and possesions, and prohibited operations in Alaska and over routes operated by certificated helicopter operators. Part 298 had a limited life and had to be renewed by the CAB. In 1965 part 298 was extended indefinitely and third-level carriers were given the right to operate unrestricted in territories and possessions and to carry the mail over noncertificated routes on a nonsubsidy basis until December 17, 1968. This, in conjunction with route strengthening and jet equipment for local service carriers, caused a rapid increase in the growth rate of third-level airlines. In October 1967 the mail authority was extended indefinitely and third-level carriers were allowed to compete for mail contracts on certificated carriers' routes. In 1968 joint fares with certificated carriers were approved. In 1969 minimum liability insurance requirements were imposed and "commuter air carriers" were created. Commuter air carriers were required to file quarterly traffic reports and to either complete five round trips per week pursuant to a published flight schedule and/or transport mail under contract to the U. S. Post Office Department. They were still prohibited from competing with certificated carriers for passengers or mail in Alaska. In 1972 the aircraft size limit was raised to 30 passengers or 7500 pounds payload with no restriction on GTOW.[5]

1.3.3 Financial History of Third-level Airlines

It has been widely held that third-level carriers have had a high failure rate for financial reasons. Between 1970, when third-level carriers began increased reporting to the Civil Aeronautics Board, and 1975 only 8 of the top 50 third-level carriers reporting in 1970 had failed, for financial reasons. This is a failure rate of 3.4% per year. Trunk carriers have had a failure rate of 1.6% per year since 1938 and local service carriers a rate of 3.8% per year since 1949 for financial reasons. Failures of certificated carriers, however, have not necessarily resulted in service reductions because failures have resulted in airline mergers.[6]

The third-level airline failure rate for financial reasons should have been higher:

1. They are in the least lucrative markets, many of which have already been abandoned by certificated carriers.

2. The industry is still in the formative stages.

3. They have lacked the government subsidy originally provided to certificated carriers.

4. They have not been well received.

The fourth point has been particularly damaging and deserves further consideration.

1. Communities have rejected third-level service if certificated service was available because the certificated carrier may leave causing the community's image to suffer and causing the communities to lose funds from the federal government: Airport Development Aid Program (ADAP) funds, Facilities and Equipment (F&E) funds, and Research, Engineering and Development (RE&D) funds.

2. Certificated airlines tend to accept third-levels in direct proportion to the traffic that third-levels feed into their systems and tend to reject them in direct proportion to the competition they represent and the traffic they feed to other carriers.

3. Contracted services such as fuel and credit cards will not give the favorable terms to third-levels that they give to certificate holders.

4. Airport authorities often put them at a different location on the airport, causing a hardship for connecting passengers, because they are not cost-effective in terms of ramp space or gates.

5. The Air Line Pilot's Association (ALPA) has used the courts in everyway possible to forestall or eradicate third-levels as a threat to their members--despite the fact that a branch of ALPA, the Union of Professional Airmen (UPA), represents, or at least purports to represent, the pilots of several third-level airlines.

6. The investment community, which could help third-level airlines with financial wisdom and resources, has been reluctant because of exaggerated prospects of financial failure or, in some cases, the prospects of liability in the event of an accident.

7. The Civil Aeronautics Board has taken the position that a third-level airline developing a new route does so at its peril because the "public interest" is always served when it is replaced by certificated service. The financial commitment of a noncertifiated carrier is not a valid consideration, according to the CAB.[7]

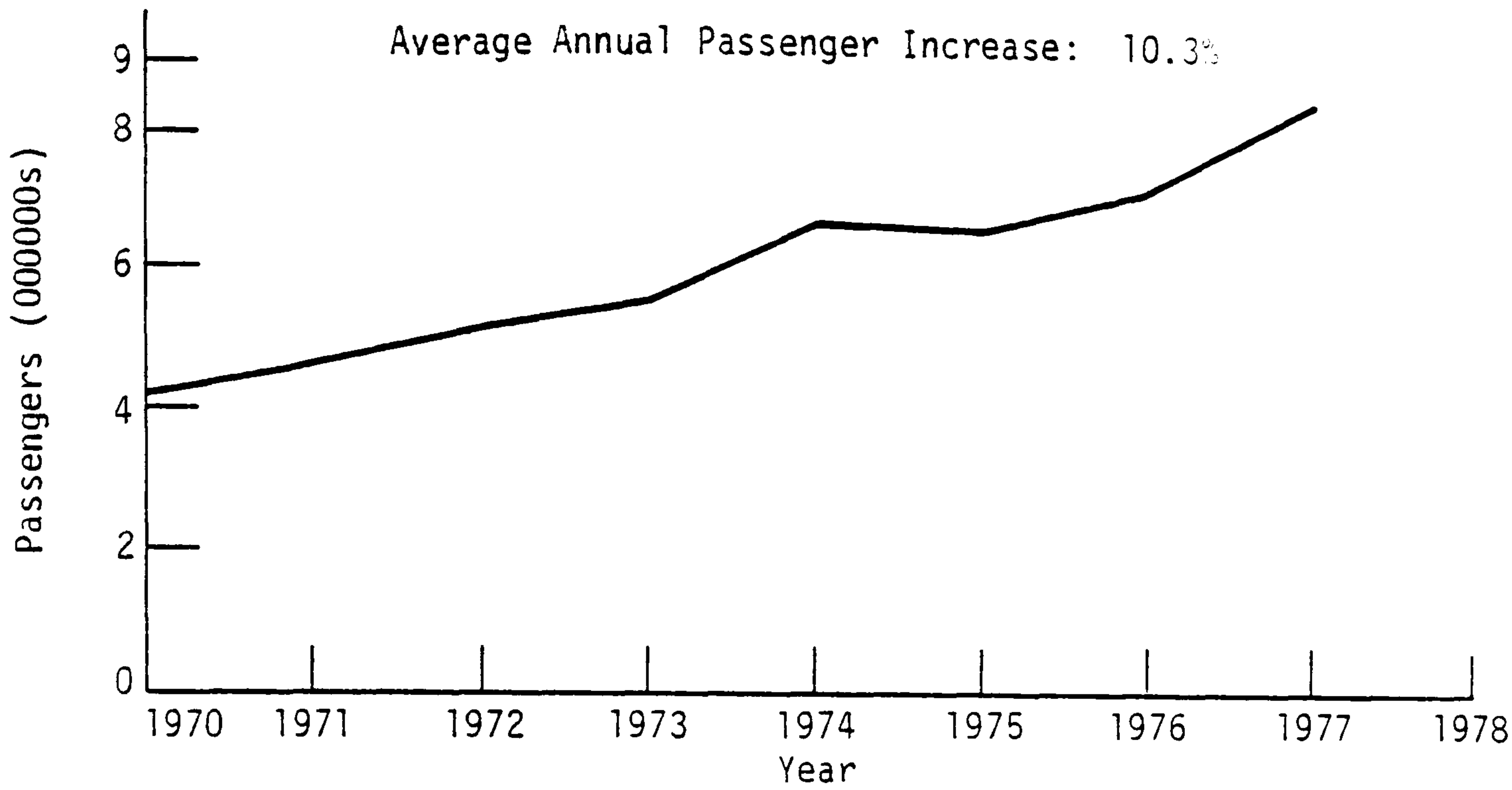
When third-level carriers do fail financially, they have generally done so shortly after initiating service. One reason is managerial incompetence. While managers are often former fixed-base operators (FBOs) with an excellent operations background, they frequently show a lack of understanding of aviation economics. The problem may be a misunderstanding of the inter-relationship of price, frequency, and reliability. It might be a "try it and see" approach coupled with a lack of market research, the inability to recognize a market's maturity, and ineffective advertising. Or, perhaps they select the wrong aircraft. Most of these are capable of producing negative cash flows sufficient to cause failure in what might otherwise be a profitable operation.

Competing with certificated carriers is usually poor judgment. The operator picks a market a certificated carrier isn't serving properly or that he feels the certificated carrier isn't interested in promoting. If the certificated carrier decides to fight for the market, the third-level carrier will likely lose because he lacks government subsidy (if available), is legally restricted from operating comparable equipment, and lacks the attractiveness of an extensive route network. If the certificated carrier does not react, the third-level operator may realize only a small percentage of the demand he induces onto the system. Travelers will recognize the greater service now available, but will try and arrange trips so that at least one portion of the journey will be on the larger, faster, more comfortable aircraft of the certificated carrier.

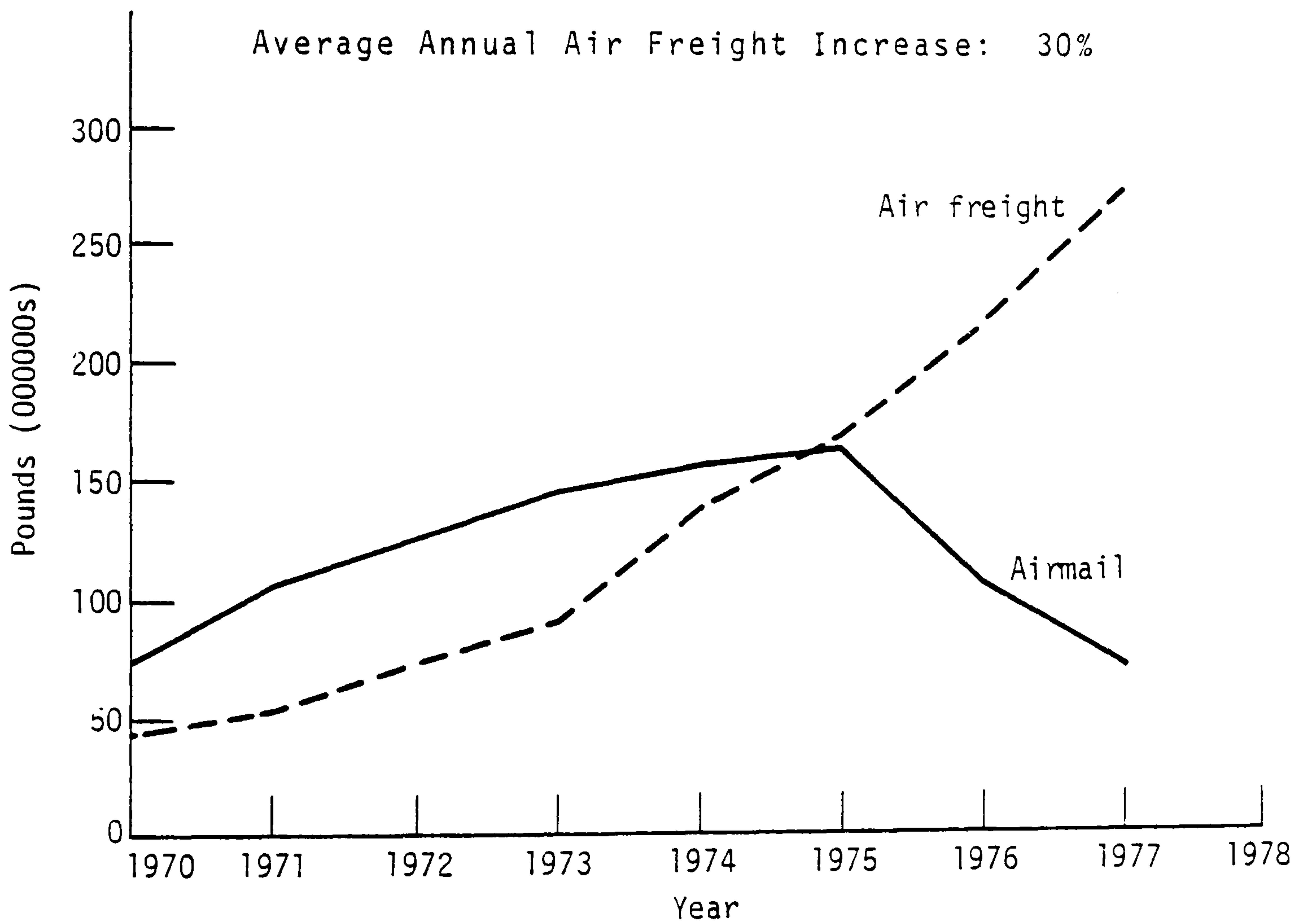
1.3.4 Growth of Third-Level Airlines

Third-level airlines have become the fastest growing segment of the airline industry in the United States. Between 1971 and 1977, annual growth of domestic revenue-passenger-miles was 6.2% for trunk, 9.3% for local service, and 12.4% for third-level carriers. Third-level growth in passengers boarded and thousands of pounds of air freight and airmail is shown in Figure 1-1.[4] In 1975 the U. S. Postal Service reversed its previous position of awarding airmail contracts to third-levels, accounting for the drop in airmail since 1975.

There are now 35 certificated carriers serving 629 airports, 144 of which have certificated service exclusively, and 242 third-level carriers serving 764 airports, 279 of which have third-level service exclusively.[4]



Third-level Passenger Growth



Third-Level Air Freight and Airmail Growth

FIGURE 1-1
THIRD-LEVEL AIR TRAFFIC ACTIVITY

1.4 Scope of the Investigation

Third-level airlines representative of the sixteen most productive carriers were investigated. This segment was chosen for four reasons:

1. They represent the largest segment of the industry from the standpoint of production. These sixteen carriers board 50.5% of the passengers and produce 47.5% of the revenue-passenger-miles. (There were 242 third-level carriers in 1977.)[4]

2. This study is only searching for profitable situations. Previous studies have been preoccupied with the provision of service to truly marginal points because the federal or state agencies funding these studies have been interested in maximum service not maximum profit.

3. All the carriers in the study had at least a four-year history of operations, were growing and financially stable, and operated all-turbine fleets.

4. It appeared the area chosen as an example, the state of Oregon, would support profitably an operation the size of the data base airlines.

1.5 Methodology

There are many methodologies that could have been used in the analysis. The emphasis in this analysis was on quantitative methods; a quantitative method was always chosen over an equally applicable qualitative method. Likewise, new methods were preferred over equally applicable older methods. A comparison of methodologies was not done.

1.5.1 Previous Studies

Past government studies have centered on analyzing and projecting past statistics of the industry. However, the CAB and Department of Transportation have twice[4,8] looked deeper into other aspects of third-level operations (specifically, costs and break-even points for government policy considerations). The Aerospace Corporation, a Federal Contract Research Center (FCRC), has done several studies on the operation of third-level airlines,[9,10,11,12,13] but the methods were proprietary and the studies could not be duplicated from the information given.

The Massachusetts Institute of Technology's Flight Transportation Lab has also done work in the third-level airline field,[3,5] but only twice studied a specific case.[14,15] R. L. Banks and Associates did a study for the State of Arizona, but the methodology was not explained.[16] Systems Analysis Research Corporation (SARC) did a study for the State of Florida where the methodology was, again, unexplained.[17] Hence, one of the aims of the present study is to explain one methodology, or system, by which third-level airlines can be analyzed financially.

1.5.2 Systems Analysis

In this analysis, a third-level airline is treated as a system, composed of appropriate economic, engineering, and mathematical models. These models provide an objective and logical framework for variable interaction where there is no opportunity for experimental research. The analytical models which compose the systems are hypothetical relationships between dependent (unknown) and independent (presumed known) variables.[18]

The steps in developing analytical models are given below.

1. Identification and selection of relevant factors and the variables which represent them.

2. Determination of the type of functional relationships between the dependent and independent variables.

3. Empirical testing of the mathematical relationship between the variables.

4. Forecasts of the new (cross-sectional) or future (time-series) independent variables and subsequent derivation of the dependent variable.

The modeling technique giving the required accuracy, using the best data, being the easiest to implement, and having the lowest cost should be used. Thus, a model may be a compromise of fidelity, data availability, complexity, and cost. At any point in the modeling process, the model may prove unacceptable. Therefore, modeling is inherently an iterative process and, usually, the more important the model or dependent variable the further the process is pursued.

Since real-world airline supply, demand, and cost functions are too complex and interwoven to be completely represented explicitly, there will be an error term associated with the models resulting from excluded variables and variable interactions. The error may also be caused or increased by inaccuracies in the measurement of the variables. This error term is explicitly accounted for as a frequency distribution about the most-likely value in the final simulation of the airline by the method known as risk analysis (Section 1.5.3.3).

By far the most important factor in developing the models was data availability. In competitive industries, such as third-level airlines, which are privately held, where no public disclosure of financial data is required, and no auditing of reported data is conducted, it is extremely difficult to obtain proprietary information. Of the sixteen third-level airlines contacted, twelve agreed to visits and five agreed to provide the required data. The data from four airlines was used in the analysis (the single all-cargo airline's data was, unfortunately, incompatible with the others). Of these four airlines, one provided four years of operating statistics and financial statements, two provided three years of data, and one provided one year of data. This resulted in a small data base, but excellent models were obtained, with a few exceptions.

To make optimum use of proprietary data and the data available to the public, the study employs four modeling techniques: Multiple Regression Analysis or the Method-of-Least-Squares (Appendix A); Subjective Probability Distributions (Appendix B); Weighted Random Walks (Appendix C); and the third-level industry's "rules-of-thumb" as obtained from manufacturers or other reports and verified by the airline's management, operating statistics, and financial accounts.

There are two defects with analytical models. First, the solutions are feasible, but not optimal, implying a better solution may be available. Second, the analysis is only as good as the forecaster or input.

1.5.3 Financial Analysis

With the appropriate models, relevant airline revenues and costs may be obtained. It is then necessary to analyze the timings and magnitudes of the revenues and costs to make the proper investment decision.

1.5.3.1 The Cost of Capital

The first item that a new venture must purchase is capital. The exact determination of the cost of capital can be an intricate problem, but the factors which should be considered include these:

1. The organization's historic rate-of-return on capital.
2. The average rate ruling in the industry.
3. Any rate prescribed by the government.
4. Rates currently obtainable on government securities.

The first two are next to impossible to obtain in the third-level industry. The airlines are usually owned by an individual or small group (≤ 10) of individuals (subchapter S corporation). The tax situation of the owner(s), whether or not the owner(s) is a salaried employee of the airline, and the expense account arrangements of the owner(s), all make the cost of capital or return-on-investment impossible to determine.

The cost of equity is the dividend yield plus the annual growth divided by the equity position or the earnings-price ratio. The cost of debt is the interest expense divided by the long-term debt. The average-weighted cost of capital is the fraction of total investment in debt multiplied by the cost of debt plus the fraction of total investment in equity multiplied by the cost of equity.

One third-level airline, Air Wisconsin, is publicly held. Its cost of capital after taxes was 6.8% in 1973, 8.4% in 1974, and 9.6% in 1975. This was based on a 10.7% cost of equity, 3.8% cost of debt, and a 57.3%/42.7% debt/equity ratio in 1973; 15.7% cost of equity, 4.2% cost of debt, and a 62.9%/37.1% debt/equity ratio in 1974; and 15.9% cost of equity, 5.3% cost of debt, and a 59.5%/40.5% debt/equity ratio in 1975.

The CAB in 1974, in the Domestic Passenger Fare Investigation (DPFI) phase 8[19], determined that the trunk airlines return-on-investment should be 12%; based on a 6.2% cost of debt, 16.75% cost of equity, and a 45%/55% debt/equity ratio.

For the local service carriers the return-on-investment determined was 12.35%; based on a 7.25% cost of debt, a 20% cost of equity, and a 60%/40% debt/equity ratio. In the investigation of flow-through subsidy to Air Midwest, the CAB determined that 12.35% was also appropriate for Air Midwest, a third-level airline.[20]

The CAB defined return-on-investment as:[21]

$$\text{Return-on-Investment} = \frac{\text{Net Profit After Taxes, But Before Interest}}{\text{Equity Plus Long Term Debt}}$$

Interest is added back into net profit after taxes since the rate-of-return is based on total investment and interest expense represents a return-on-debt.

There is a problem with this "fixed" approach. With changing inflation and floating-point loans, the cost of debt will change. Second, throughout the airline's history its debt/equity ratio may change. There also is a problem with leased aircraft. They are not carried on the balance sheet and, hence, they are not shown as debt even though lease payments are just as binding as bank notes. This can result in optimistic returns-on-investment because of less apparent total investment.

It is common to raise the discount rate to account for risk in appraising projects. This can be a mistake. If risk analysis is employed (Section 1.5.3.3), risk is already explicitly accounted for by better means. In a new project the risks come early, but an elevated discount rate greatly deflates the later cashflows when the project may be either highly successful and nearly risk free or long since bankrupt.

Thirteen percent (13%) was selected as the average-weighted cost of capital or discount rate. It is used for initial set-up and the analysis of support activities, e.g., rate-per-hour contracts, evaluation of the avionics shop. Its importance is diminished by the final analysis of the airline at several discount rates (Section 6.3.5.3) which creates a continuous curve that gives the airline's performance at any discount rate. With the continuous curve, it is possible to analyze the investment for all reasonable constant costs of equity and debt, and debt/equity ratios.

1.5.3.2 Methods of Investment Appraisal

There are four methods of investment appraisal using cashflows. Table 1-1[22] summarizes investment appraisal techniques in current use. The first two methods, payback period and accounting-rate-of-return, both ignore the time value of money, e.g., the outlays and proceeds regardless of when they occur are treated equally. The concept of the time value of money is that: it is better to have $1

TABLE 1-1

SUMMARY OF INVESTMENT APPRAISAL METHODS[22]

Method	Definition	Computation	Advantages	Disadvantages
Payback Period (PB)	Number of years until investment is recouped.	If rate of cashflow is constant $PB = \frac{\text{Investment}}{\text{Net Cashflow}}$ otherwise, the payback is determined by adding up the expected cash inflows until the total equals the initial investment.	1. Simple to use and understand. 2. Makes allowances for risk attitudes. 3. Commonly known and used.	1. Ignores cashflow beyond payback period. 2. Ignores timing within payback period. 3. Overemphasizes liquidity as investment criterion.
Accounting (or Unadjusted) Rate of Return	Ratio of average annual income after depreciation to the average book value of the investment.	$\frac{\begin{bmatrix}\text{Average}\\ \text{Annual Cash}\\ \text{Inflow}\end{bmatrix} - \begin{bmatrix}\text{Average}\\ \text{Annual}\\ \text{Deprec.}\end{bmatrix}}{\text{1/2 Initial Investment}}$	1. Easy to compute and understand. 2. Commonly known and used.	1. Ignores timing of cash flows.

TABLE 1-1
(concl'd)

SUMMARY OF INVESTMENT APPRAISAL METHODS

Method	Definition	Computation	Advantages	Disadvantages
IRR (Internal Rate of Return or Return On Investment in %)	Discount rate which makes the net-present-value of inflows and outflows equal to zero.	The IRR is determined by solving the equation $0 = \sum_{t=1}^{T} \frac{CF_t}{(1 + IRR/100)^t}$ where CF_t = Net Cashflow at time period t after taxes, but before interest; T = Planning Horizon	1. Takes time value of money into account. 2. Does not require definition of a discount rate. 3. Intuitively appealing.	1. Computationally complex (requires trial and error). 2. Assumes other investment opportunities exist at same IRR. 3. Does not consider size or scale of the investment. 4. Occasionally provides more than one discount rate, or none (multiple solutions). 5. In simulation[23] $P[IRR < I] > P[NPV < 0\|_I]$ is difficult to interpret. 6. In simulation[23] $E[IRR] > E\left[\left(\sum_{m=1}^{M} IRR\right) \div M\right]$
Net-Present-Value (NPV)	Difference between cash inflows and outflows discounted to the present at a given interest rate.	$NPV = \sum_{t=1}^{T} \frac{CF_t}{(1 + I/100)^t}$; I = Interest Rate (%)	1. Takes time value of money into account. 2. Easier to compute. 3. Gives change in stockholder wealth.	1. Requires definition of a discount rate. 2. Less intuitive than IRR.

now that can be invested to yield \$1+ a year from now than to receive just \$1 a year from now. Hence, not only the amount of the money, but when it is received is important. This concept is too important to ignore, so payback period and accounting-rate-of-return are rejected for investment appraisal in this analysis.

The internal-rate-of-return (IRR) or return-on-investment (ROI) takes the time value of money into account and is defined by:

$$\sum_{t=1}^{T} \frac{CF_t}{(1+ (IRR/100))^t} = 0$$

where

CF_t is the after-tax cashflow before interest expense,

IRR is the internal-rate-of-return in percent (%), and

T is the planning horizon or period over which the investment is evaluated.

The IRR can occasionally provide more than one solution with more than one major investment period. Multiple solutions can be eliminated by discounting debt at the payrate (cost of debt) and discounting earnings at the earnrate (cost of equity). This runs counter to the current theory that both should be discounted at the average-weighted cost of capital (Section 1.5.3.1).

Item 5 under IRR disadvantages (Table 1-1) means that the expected IRR in a Monte Carlo simulation will be less than the discount rate for which the net-present-value is zero. This is because the denominator in the equation increases geometrically with time. Item 6 says the expected rate-of-return will normally exceed the mean of the simulated returns, again, the reason is because the denominator increases geometrically with time.[23] For example, suppose there was a project that was simulated twice and that this project had only two cashflows: one dollar out in year one and one positive-cashflow in year ten. The first simulation gives a positive cashflow of \$2.59 in year ten. So, its IRR is 10%. The second simulation has a cashflow twice that of the first simulation or \$5.18 in year ten. Its IRR of 17.9% is less than the "expected" 20%.

The net-present-value (NPV) also accounts for the timing of cashflows. It is the method of investment appraisal that is used in this analysis. Net-present-value is defined by:

$$NPV = \sum_{t=1}^{T} \frac{CF_t}{(1+i/100)^t}$$

where

CF_t is the after-tax cashflow before interest expense, i is the interest, discount rate or average-weighted cost of capital in percent (%), and

T is the planning horizon or period over which the investment is evaluated.

NPV is best explained by an example. Suppose a company with X shares outstanding selling at Y dollars has an average-weighted cost of capital, i. It now undertakes a new project with the same cost of capital which has discounted positive cashflows (proceeds) of value P and discounted negative cashflows of value N. With no investment the new stock value, Y_1, of each share is $Y_1 = Y + (P-N/X)$. This implies that to undertake the project, and not devalue the stock outstanding, $P \geq N$. Or, that N, the discounted investment, should never exceed P, the discounted return, i.e., the net-present-value should always be positive.

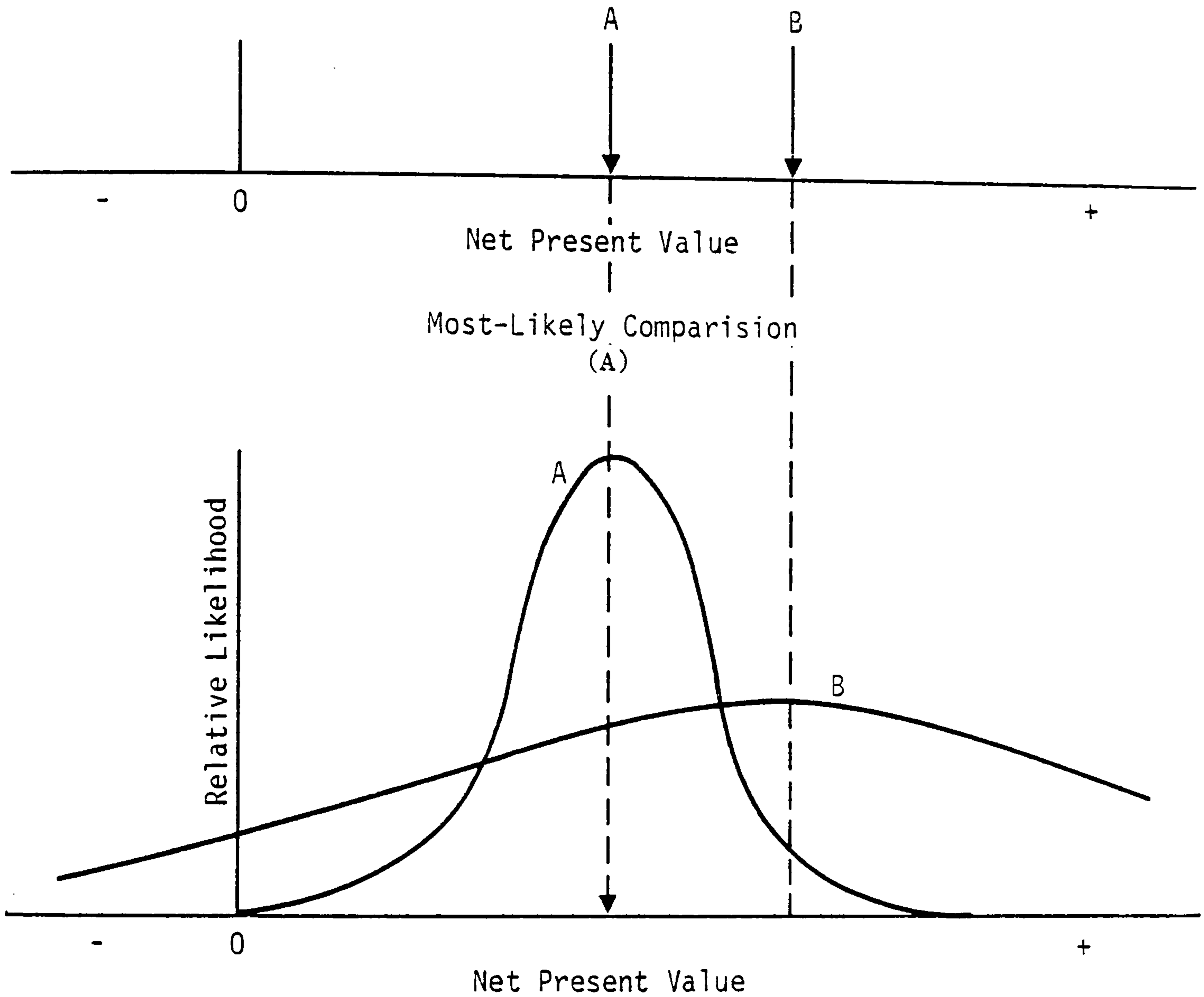
By setting an appropriate discount rate, i = 13%, it is possible to compare alternatives such as in-house or contracted maintenance and make an estimate as to their affect on stock value. With the internal-rate-of-return it is possible to choose between the alternatives, but it is not possible to tell how they would affect stock value.

1.5.3.3 Risk Analysis

Traditional financial analysis assumes that the inputs to the model are the most-likely values and, hence, single-valued. Their use, in turn, results in single-valued outputs. This implies that the analyst knows future quantities with certainty.

Figure 1-2A illustrates the comparison of two alternatives under conditions of certainty, the most-likely values being A and B. In this context B is superior. However, if the probability distributions take the form shown in Figure 1-2B, the choice is no longer obvious and depends on the analyst's aversion to risk. B offers the opportunity for large rewards, but it also offers the prospect of loss. Alternative A has a better defined set of outcomes with little opportunity for large rewards, but no prospect of loss.

Consider the situation where profit, P, is given by P = R - (A+B+C+D) where R represents revenue and A,B,C, and D are expense items. In conventional analysis most-likely estimates are made for R and A,B,C, and D. Suppose the most-likely profit, P, is found to be 1.00. Given the same most-likley values for R and A,B,C, and D, their associated probability distributions are shown in Figure 1-3.[24] When the probability distributions are taken into account, the equation P = R - (A+B+C+D) yields the probability distribution of P. The most-likely value for P is now 0.22, a significant difference from the use of most-likely values alone, P = 1.00. This discrepancy results from the property of mathematically expected values adding to yield the expected value of their sum, while most-likely values do not add to yield the most-likely value of their sum unless their probability distributions are unskewed (symmetrical).[24] But when a large number of skewed distributions are input the output probability distribution tends to become normal or Gaussian and its expected and most-likely values tend to converge.[23]



Risk Comparison
(B)

FIGURE 1-2
COMPARISON OF ALTERNATIVES

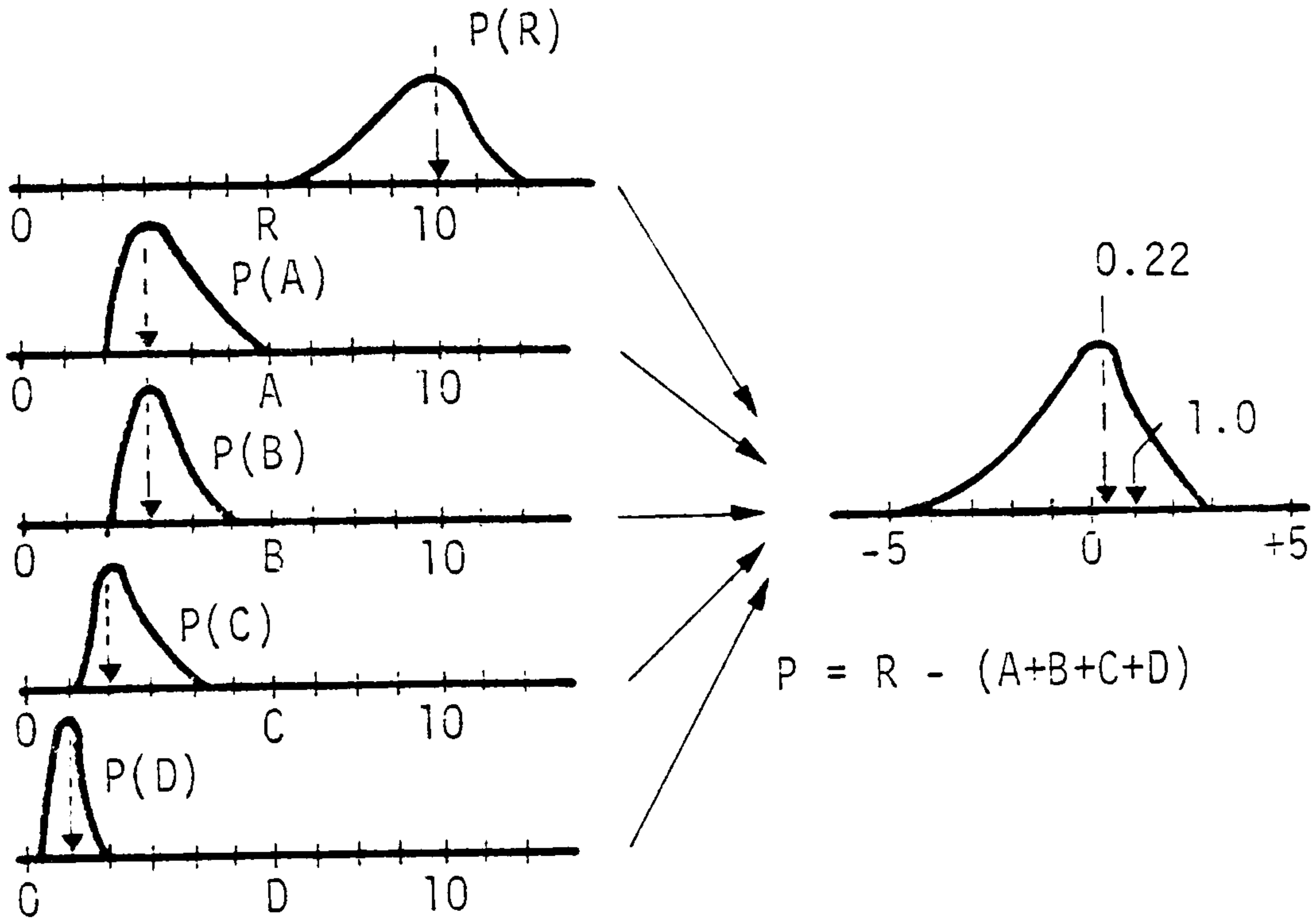


FIGURE 1-3
COMPUTATION OF MOST-LIKELY PROFIT

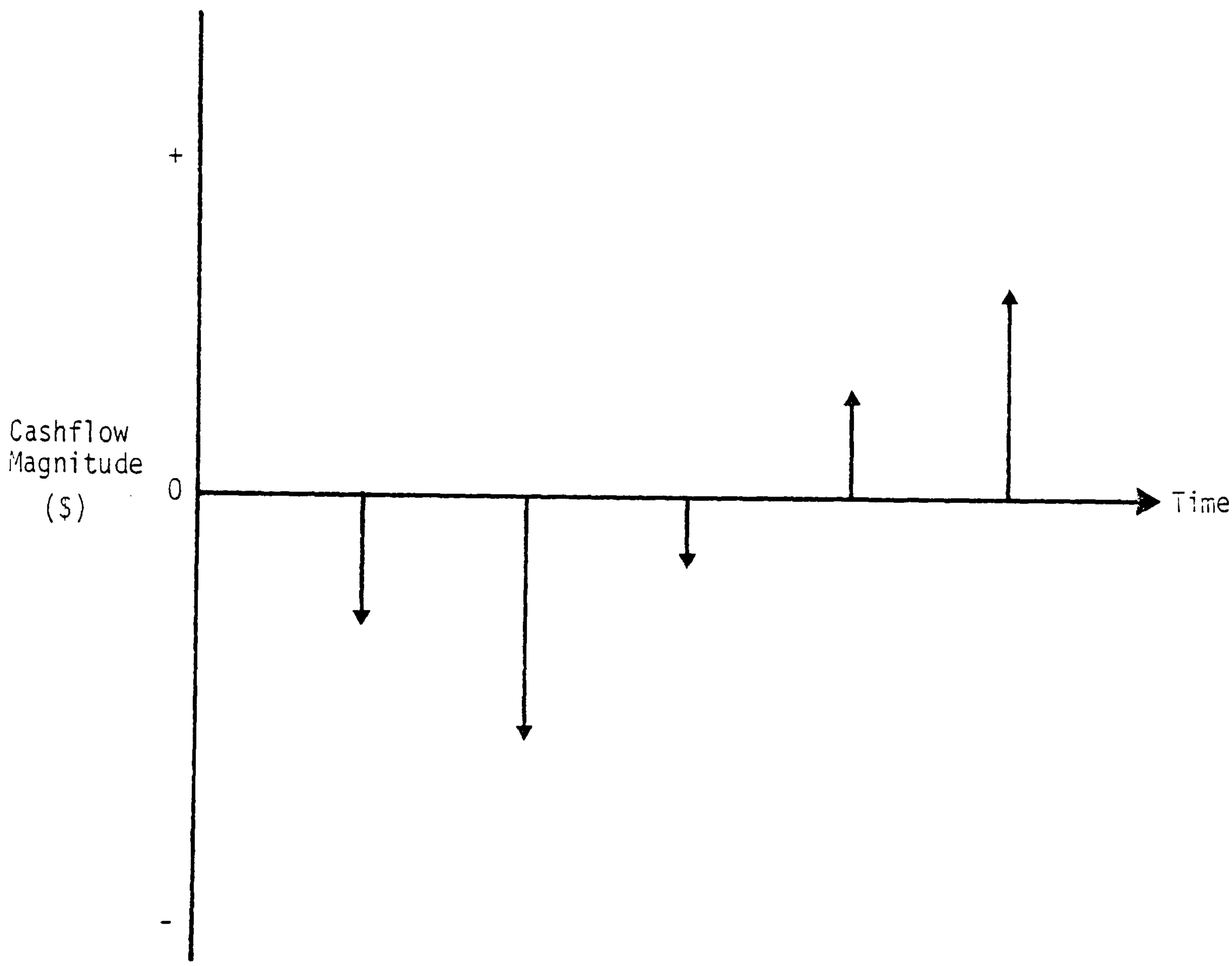


FIGURE 1-4
CONVENTIONAL ANALYSIS OF CASHFLOW

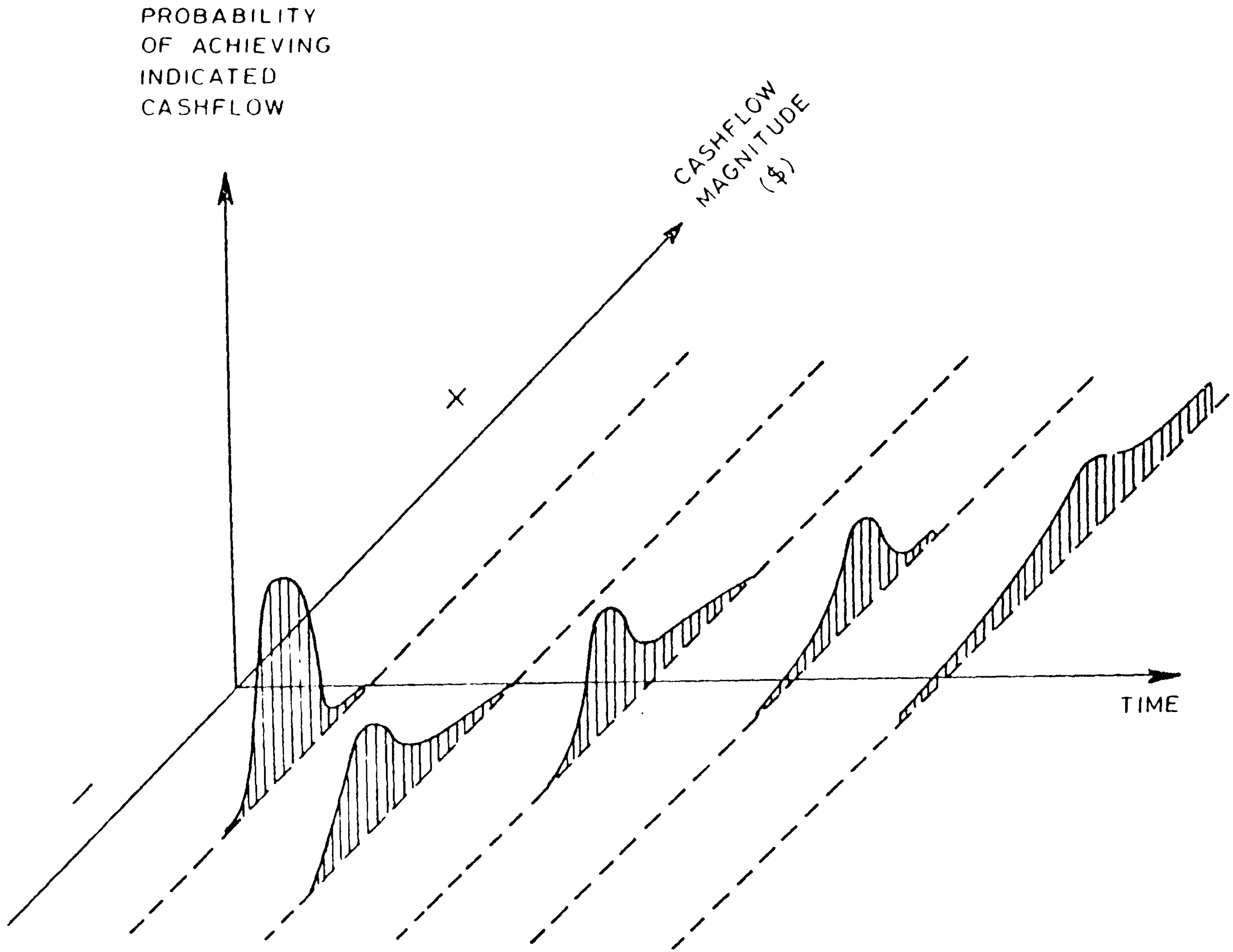


FIGURE 1-5
PROBABILITY ANALYSIS OF CASHFLOW

In traditional cashflow techniques, the cashflows in any time period are single-valued resulting in a two-dimensional analysis, magnitude versus time (Figure 1-4). Risk analysis requires a third dimension, probability or relative likelihood (Figure 1-5). The selected cashflow in one time period may be dependent on the cashflow in the previous time period and may influence the cashflows in subsequent periods, but not to the degree in a most-likely analysis.

The analysis of cashflows described by probability distributions yields net-present-value (NPV) as a probability distribution and the decision-maker must now select the alternative which maximizes utility, U, given by:

$$U = \int_{-\infty}^{+\infty} U(NPV)\ P(NPV)\ dNPV$$

where

NPV is the net present value,

U(NPV) is the utility function in terms of NPV, and

P(NPV) is the probability of achieving the NPV.[24]

Lastly, the various expenses and/or revenue elements in the analysis may be correlated. The correlations are difficult to detect and mishandling them can be disastrous.[23] And, they are basically unfamiliar because they're not required for most-likely estimates. To limit disaggregation is to solve the problem of correlation by ignoring it; the advantage of risk analysis is that it permits disaggregation.

Risk analysis, then, requires some knowledge of the relative likelihood and correlation of possible events. This necessitates a more detailed knowledge than merely estimating the most-likely values. In this analysis many of the quantities were estimated by the use of regression equations which have explicit probability distributions associated with them, Appendix A. Other means of developing probability distributions are given in Appendix B (Subjective Probability Distributions) and Appendix C (Weighted Random Walks), for variables unobtainable by regression.

1.6 The State of Oregon

The state of Oregon was chosen as a representative example because on April 30, 1973 Hughes Airwest, a certificated carrier, ceased serving five cities in Oregon: Astoria, Baker, Corvallis-Albany, Ontario, and Roseburg. If Hughes Airwest achieves its goal of an all-jet fleet by the end of 1977, North Bend-Coos Bay will also lose service because of runway length considerations.* Furthermore, United Airlines claims that both Salem and Pendleton are uneconomical on its system.[10] Pendleton and Salem are highly vulnerable to service loss as the CAB has been more disposed to letting the unsubsidized trunk carriers exit markets than the subsidized local service carriers.

* North Bend-Coos Bay lost service from Hughes Airwest on July 1, 1979.

In addition, according to the CAB, existing service is inadequate at Klamath Falls, North Bend-Coos Bay, Pendleton, Redmond-Bend, and Salem* because less than two round trips per day are provided.[44] A map of Oregon is shown in Figure 1-6.

1.6.1 Initial Assumptions in Oregon

Even though the methodology allows wide latitude for uncertainty and risk, certain initial assumptions are necessary to obtain answers within reasonable bounds. These assumptions are given below.

1. That the required funding would be fully available at the time of incorporation.

2. That United Airlines and Hughes Airwest, given the opportunity, would suspend service at Klamath Falls, North Bend-Coos Bay, Pendleton, Redmond-Bend, and Salem.

3. That one of the certificated carriers would be willing to dedicate at least one aircraft to serving passengers departing through Medford to San Francisco and to serving passengers departing San Franciso to and through Medford for Oregon cities four times per day at times agreed with the third-level airline.

4. That the airframe manufacturer could supply aircraft at the rate of one and a half aircraft per month for seven months commencing six months from incorporation.

5. For investment appraisal purposes, the airline is operated for ten years. The aircraft purchased initially will have useful lives of about ten years. This analysis avoids the re-equipping question because:

    a. The regulatory changes may greatly affect the type of aircraft allowable.

    b. There are no aircraft nearing production that would be more suitable than those available today (30 seats or less).

    c. The magnitude of the investment coupled with a ten-year projection requirement would overshadow the shorter-term investment results.

1.7 Elements of the Analysis

There are certain elements that must be considered in the analysis of any third-level airline, whether in Oregon or elsewhere. Some may be available from historical data, manufacturers, other operators, the communities, and some the analyst may have to develop. The emphasis in this analysis is on development for those elements which may not be readily available.

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* Salem lost service from United Air Lines on March 8, 1980.

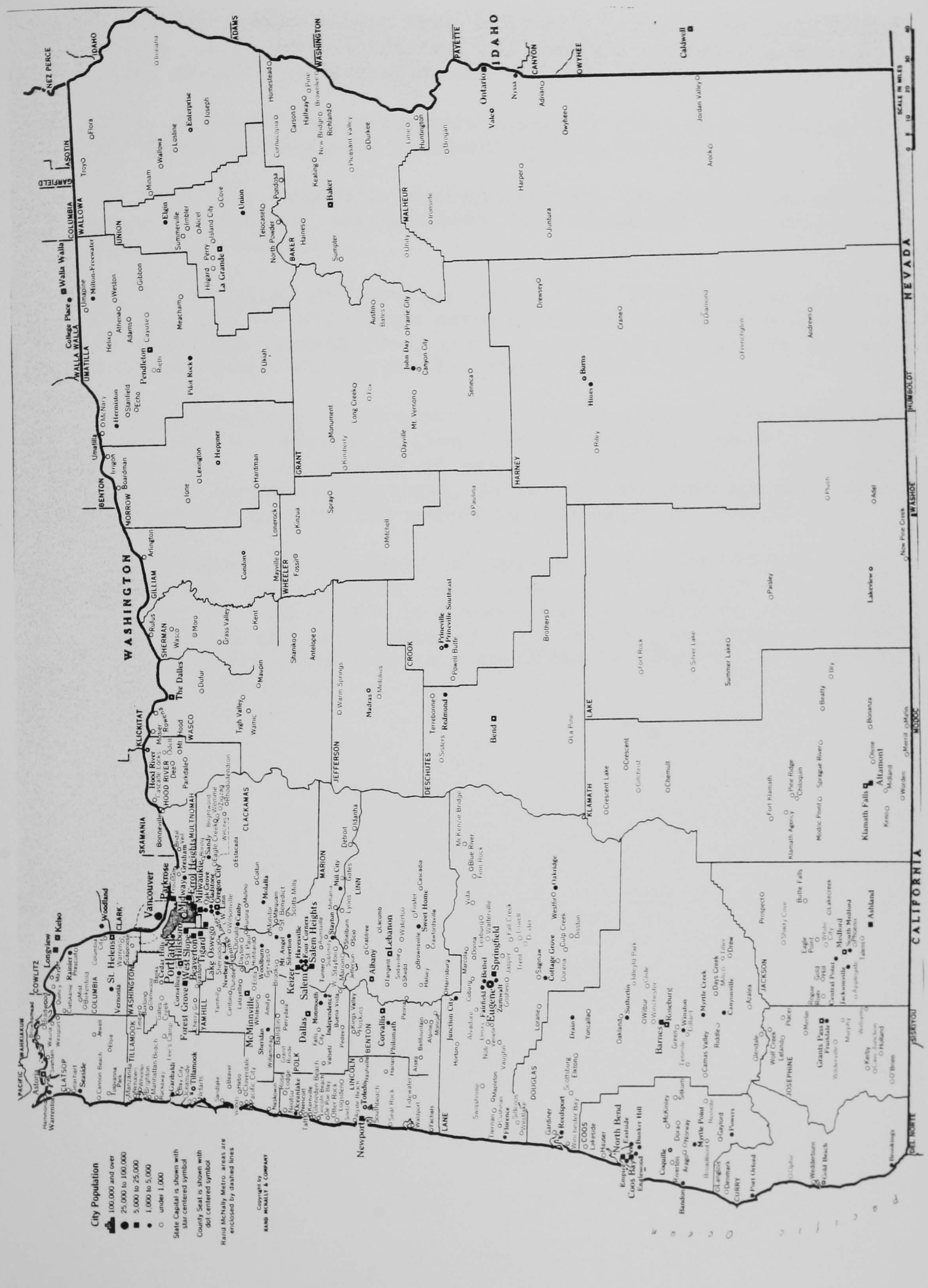

FIGURE 1-6
OREGON

The following are the basic elements required to analyze the institution and subsequent operation of a third-level airline:

1. Travel demand models that accurately predict the demand for service under the conditions of service offered (frequency, price, reliability, competing modes, etc.), Section 2.

2. Cost models that accurately represent costs as a function of the demand, service, and equipment offered, Section 3.

3. Models of supportive activities where the airline has alternative investment opportunities for optimizing its return-on-investment, Section 4.

4. A scheduling and pricing policy that maximizes the service provided and the difference between revenue and variable costs to yield maximum contribution, the short-term counterpart to maximum return-on-investment in the long-term, Section 5.

5. An accounting is necessary of how the steady-state solutions of element 4 change with time (traffic build-up, growth, inflation, etc.), the effects of one-time start-up costs, different financial decisions (purchase, lease, tax shelter) and the error terms of the model by the method of risk analysis, Section 6.

The above elements are developed in subsequent sections and yield both the most-likely and feasible solutions. They will not yield the optimal solution that would be sought by an agressive, responsive management in the day-to-day operation of the airline; there are such a myriad of possibilities that they could not be simulated by even the most sophisticated model.

2. AIR TRAVEL DEMAND

2.1 Introduction

Air travel in Oregon is assumed to consist of three components: intra-Oregon passenger travel, which has intrastate destinations; connecting passenger travel, which has interstate destinations; and air freight and airmail, which may have either intrastate or interstate destinations. In this section these three models are developed.

From the standpoint of financial prediction, these models are by far the most important. For example, a relatively cost-efficient third-level airline may have a cost per revenue-passenger-mile 9% below the expected cost, and a relatively cost-inefficient airline may have a cost per revenue-passenger-mile 9% above the expected cost. With a 19 passenger aircraft and an expected break-even load factor of 28% (5.34 passengers per flight), one passenger per flight represents more than could be achieved by changing the operation from one of low-cost efficiency to one of high-cost efficiency.

2.2 Air Travel Demand Factors

There are many influencing factors which can be considered when developing econometric models for predicting travel demand between two towns or areas. These include international, national and local economic, political and social conditions, demographics, mutual affinities between areas, psychological factors, competition from other modes and other airlines, and government regulations.[25] The influence of these travel demand factors is varied, some are independent and others interdependent. Some are constant, others may change over a long period, and others may change immediately. Without a doubt, a quantifiable measure of each one has, at sometime or other, been tried in an air traffic model. Often they are entered as aggregate quantities representing an entire area rather than as quantities representing each potential air traveler within the area. This is reasonable considering modeling constraints. But it must be remembered that: it is not the collective or even real individual quantities that count, only the values as perceived by the consumer.

Most practical formulations of travel demand models have the following:[25]

1. A socioeconomic component (population, income, population having incomes above a certain level, etc).

2. A general impedance component (price, sum of generalized costs, time, etc.).

3. A quality-of-service component which acknowledges other modes in some form (frequency, time of departure, reliability, etc.).

2.3 Methodology

The modeling method used is the method-of-least-squares or multiple regression analysis (Appendix A).

The reasons for selecting multiple regression are given below.

1. It is an accepted technique for this type of work and has been used effectively in the past.

2. In forecasting, it can be used to produce probability distributions which subsequently may be used in a risk analysis program; this feature is extremely important to this study.

3. It works for both cross-sectional and time-series analysis.

4. Regression packages are universally available.

5. Data acquisition and analysis can often be done by one individual due to the nature of the data required.

When regression techniques are employed it should be remembered that:

1. Developing a demand model to fit data is easy. Ensuring that the elasticities of the independent variables actually predict the effects of changing the independent variables is much more difficult.

2. Neither the assumption of base mode specificity, where each mode's real value is used, or base mode abstractness, where mode values are normalized by one mode (usually the optimal mode) is preferable.[26]

3. Problems of multicollinearity can exist in commonly quantifiable factors:

   a. Ticket price, personal income, population and travel are positively correlated with time.

   b. Travel time, travel distance, and ticket price are usually positively correlated.

   c. Population, employment and an area's annual product are usually positively correlated.

   d. In short-haul, low-density markets around a hub, items in b are negatively correlated with items in c.

   e. Flight frequency correlates positively with items in c and negatively with items in b.

Specific, additional restrictions are pertinent to this study:

1. The data bases are restricted to that information commonly available to the private sector throughout the U.S.

2. In a specific study of a small area, there are a limited number of observations available thus the number of independent variables is limited. An innovative approach is taken in this study to combine variables so that the value of the combination accurately reflects the contribution of each variable.

The development of models by regression is as much an art as a science and can involve hundreds of iterations in the search for causal independent variables that correctly explain the behavior of the dependent variable. In this study only the last iterations and the reasons for the inclusion of the final independent variables are given. With these points in mind, models for Oregon were formulated.

2.4 Air Demand Data

Passenger traffic data was obtained for the years 1969 and 1975 from "Domestic City-Pair Summary" (Table 8) by the CAB.[27] Airmail and air freight data came from Emery Airfreight, Federal Express, and "Airport Activity Statistics for Certificated Route Air Carriers" (Tables 5 and 6), which was prepared jointly by the CAB and FAA. Reliability, scheduled departures, and aircraft type and size data also came from Tables 5 and 6, and Table 7.[28] Tax return data came from the "Summary of Oregon Individual Income Tax Returns 1969", and "1975" by the Oregon Department of Revenue.[29] The history and forecasts of annual county products and annual county populations came from data sheets supplied by the Oregon Commission On Economic Development. Driving times were obtained from an American Automobile Association road map of Oregon.

2.4.1 Oregon Air Service Areas

The air service areas were defined by natural geographic barriers, driving time to the airport, accessibity of other airports, and the possibility of hyphenated service (one airport serving two towns, each town having a suitable airport). These areas are expressed in terms of counties or fractions of counties for each airport capable of supporting a viable all-weather airline operation in Oregon. During development of the model and subsequent forecasting for the third-level airline, adjustment of the service areas was sometimes necessary. For example, Baker county was served through Baker in 1969 and through Pendleton in 1975 because of a loss of air service at Baker. Union and Umatilla counties were served through Pendleton in 1969 and 1975. A third-level airline, with timely and frequent service to Baker, would serve both Union and Baker counties through Baker. There is a mountain range between Union county (La Grande) and Pendleton. Therefore, with third-level service only Umatilla county would be served through Pendleton. As long as the ratio of the calculated independent variable value (assumed airport service area) to the true independent variable value (actual airport service area) is correct for both the model and the simulation, the true value is unimportant. Driving times to the airport were based on the time from the air service area population center to the airport. Table 2-1 gives the air service area statistics.

2.5 The Intra-Oregon Travel Demand Model

Only 30-40% of third-level traffic, or true commuter traffic, is local in character. Competition from the private automobile makes intra-Oregon travel the most sensitive to socioeconomic factors, quality-of-service, and price. Multicollinearities and a limited data base restricted the number of independent variables that could be entered explicitly. Therefore, two new, composite, independent variables were developed to effectively combine several potential variables.

TABLE 2-1

AIR SERVICE AREA DEFINITIONS

Airport	County(s)	Driving time (hours) to airport
Baker	Baker[1]	0.3
Corvallis	Benton & 67% Linn	0.3
Eugene	111% Lane	0.3
Klamath Falls	107% Klamath	0.3
North Bend	115% Coos	0.3
Pendleton	Umatilla & Union[2]	0.4
Portland[3]		0.3
Redmond	Crook, Deschutes, Jefferson	0.3
Roseburg	91% Douglas	0.2
Salem	Polk & 86% Marion	0.2

1 Included in Pendleton in 1975
2 Included in Baker with third-level service
3 Handled as a dummy variable

The factors below were tried as independent variables, both explicitly and in appropriate combinations, in the intra-Oregon travel model.

1. Frequency factor (explained below)

2. Reliability

3. Product of the income-weighted taxable income distributions multiplied by the population products (explained below)

4. Dummy variables for Portland, Seattle, and San Francisco

5. Air fare

6. Jet or nonjet service availability

7. Cost of automobile gas ($/ gallon)

8. Year of the data (1969 or 1975)

9. Driving distance

10. Time differences between ground and air mode

The resulting equation is given below and the complete statistics are shown in Table 2-2.

$$OT = K1\ FF^{K2}\ R^{K3}\ PIM^{K4}\ DP^{K5}\ e^{K6(T/100)}$$

where

OT is the intra-Oregon travel demand,

K( ) is the calibrating coefficient or exponents solved for by the regression program,

FF is the frequency factor,

R is the reliability,

PIM is the product of the income-weighted taxable income distribution multiplied by the population products,

DP is a dummy variable for Portland,

e is the base of the natural logarithm, and

T is the ticket price.

Each of these factors and their exponents are explained in detail below.

K1 (2620.3) is the calibration constant.

FF, the frequency factor, was developed to account for the time of departure, the time saving available by air, and the flight frequency.

TABLE 2-2

INTRA-OREGON TRAVEL DEMAND MODEL

LOG-LOG REGRESSION OF INTRA-OREGON AIR TRAVEL (0'S) AGAINST FREQUENCY-FACTOR, SCHEDULE RELIABILITY, PRODUCT OF THE INCOME-WEIGHTED TAXABLE INCOME DISTRIBUTIONS TIMES POPULATION PRODUCTS (000000'S) EXCEPT THAT WHEN PORTLAND IS PART OF THE CITY-PAIR ONLY THE OTHER CITY'S POPULATION TIMES IT'S INCOME-WEIGHTED TAXABLE INCOME DISTRIBUTION (0000'S) IS USED, A DUMMY VARIABLE FOR PORTLAND, AND THE EXPONENT OF THE AIR FARE (00'S) IN 1975 DOLLARS.

CORRELATION COEFFICIENTS

1.000	0.604	0.451	0.440	0.600	0.177
0.604	1.000	0.076	-0.110	0.048	0.618
0.451	0.076	1.000	0.548	-0.041	-0.041
0.440	-0.110	0.548	1.000	0.078	-0.225
0.600	0.048	-0.041	0.078	1.000	0.065
0.177	0.618	-0.041	-0.225	0.065	1.000

MULTIPLE REGRESSION N= 36 M= 6

VARIABLE	MEAN	ST.DEV.	CORREL.	REG.CO.	S.E. OF R.C.	COMP. T
2	-2.44343	1.40779	0.60403	1.02386	0.04275	23.94818
3	-0.12783	0.13728	0.45074	3.59346	0.41610	8.63614
4	4.04602	0.85771	0.43957	0.64479	0.06802	9.47889
5	1.02337	1.16059	0.59990	0.95567	0.04090	23.36397
6	0.26444	0.08632	0.17744	-5.47657	0.70653	-7.75132
DEPENDENT						
1	7.04843	1.95123				

INTERCEPT 7.87104 MULTIPLE CORRELN. 0.99131 S.E. OF ESTIMATE 0.27719

ANALYSIS OF VARIATION	DF	SUM SQ	MEAN SQS.	F VALUE
ATTRIB. TO REGRESSION	5	130.95097	26.19019	340.86729
DEVIATION FROM REGRESSION	30	2.30502	0.07683	

CORR. MULT. CORRELN. 0.99105
AUTO-CORRELN. OF RES. -0.13737
VON NEUMANN RATIO 2.34121
HETEROSCEDASTIC CORRELN. -0.04034
HETEROSCEDASTIC T-COMP. -0.23540

NO.	OBS.Y	EST.Y	RESIDUAL	ORIGINAL VALUES NO.	OBS.Y	EST.Y	RESIDUAL
1	7.56008	7.35928	0.20081	1	1920.00000	1570.69812	349.30188
2	6.42972	6.50029	-0.07057	2	620.00000	665.33587	-45.33587
3	7.77486	7.66023	0.11463	3	2380.00000	2122.24564	257.75436
4	3.40120	2.93264	0.46856	4	30.00000	18.77706	11.22294
5	5.85793	6.18495	-0.32702	5	350.00000	485.39105	-135.39105
6	7.47873	7.30747	0.17127	6	1770.00000	1491.39673	278.60327
7	6.76849	7.35561	-0.58712	7	870.00000	1564.94949	-694.94949
8	8.40738	8.24776	0.15962	8	4430.00000	3819.05275	660.94725
9	2.99573	3.16111	-0.16538	9	20.00000	23.59688	-3.59688
10	7.33954	7.22551	0.11402	10	1540.00000	1374.04506	165.95494
11	7.09008	6.97676	0.11332	11	1200.00000	1071.44032	128.55968
12	6.55108	6.40428	0.14680	12	700.00000	604.42891	95.57109
13	6.23441	5.84291	0.39150	13	510.00000	344.78259	165.21741
14	6.29157	6.27940	0.01217	14	540.00000	533.46750	6.53250
15	5.48064	5.96411	-0.48347	15	240.00000	389.20673	-149.20673
16	6.60665	6.79345	-0.18680	16	740.00000	891.98951	-151.98951
17	6.23441	6.26734	-0.03293	17	510.00000	527.07465	-17.07465
18	5.82895	5.71500	0.11394	18	340.00000	303.38497	36.61503
19	3.68888	3.81177	-0.12289	19	40.00000	45.23062	-5.23062
20	2.30259	2.33302	-0.03043	20	10.00000	10.30901	-0.30901
21	9.06300	9.26952	-0.20652	21	8630.00000	10609.70673	-1979.70673
22	8.94507	9.07211	-0.12704	22	7670.00000	8709.02214	-1039.02214
23	9.38513	9.13740	0.24774	23	11910.00000	9296.54516	2613.45484
24	6.29157	6.32240	-0.03089	24	540.00000	550.94140	-10.94140
25	6.30992	6.39641	-0.08650	25	550.00000	599.69089	-49.69089
26	9.45485	9.37846	0.07639	26	12770.00000	11830.80584	939.19416
27	10.23351	10.29850	-0.06499	27	27820.00000	29688.16749	-1868.16749
28	9.30201	9.42204	-0.12003	28	10960.00000	12357.74873	-1397.74873
29	10.14408	9.96854	0.17553	29	25440.00000	21344.37770	4095.62230
30	8.84793	8.54186	0.30608	30	6960.00000	5124.84688	1835.15312
31	8.82026	8.88718	-0.06692	31	6770.00000	7238.58631	-468.58631
32	7.63046	8.20555	-0.57509	32	2060.00000	3661.21425	-1601.21425
33	9.46493	9.13463	0.33035	33	12900.00000	9270.87963	3629.12037
34	6.86693	6.40892	0.45801	34	960.00000	607.23820	352.76180
35	6.64639	6.72688	-0.08049	35	770.00000	834.54195	-64.54195
36	6.01616	6.25177	-0.23562	36	410.00000	518.93245	-108.93245

MEAN DEVIATION= 706.09

Five profiles of flight demand as a function of time of day, along with a persistence of demand function developed next, were checked for their explanatory ability in the model. They are shown in Figure 2-1. It is assumed that the shape (relative values) of these profiles are unaffected by price, frequency, reliability, alternate modes, or air service area demographics. However, the magnitudes of the profiles are affected by all of these.

Boeing Computer Services[30] developed 24 profiles based on the difference in local time of departure and local time of arrival, e.g., 0-1 hour, 1-2 hours,....,23-24 hours from United and American Airlines data for a one-year period. The profile is spline-fit to 0.1 hour intervals, as are all other profiles. This profile is the composite for Oregon and it is weighted on the basis of passengers arriving 0-1 hours after departure and passengers arriving 1-2 hours after departure, Pacific Time, the only time zone applicable. While basically a supply profile, it represents such a broad traffic base that it should accurately reflect demand. It had the least variability of flight demand throughout the day of any of the profiles tested.

The Port Authority of New York & New Jersey's profile[31] was derived from the times passengers boarded third-level services at John F. Kennedy Airport.* It is definitely a supply profile and experiences the greatest daily variation. Because of JFK's distance from the center of New York City, it is suspected that the passengers were connecting rather than local O&D to New York City. Had the data been for La Guardia or even Newark, which are both closer to the city's center, the traffic may have been more local in character.

The third profile represents an arithmetic mean of the first two profiles. It was developed by the author in hopes that it would prove a more accurate independent variable component than either of the first two profiles for intra-Oregon demand forecasting.

Eastern Airline Shuttle data for 1967 was compiled as a profile by MIT.[32] Because of the nature of a shuttle service, it best represents a pure demand profile throughout that part of the day when the shuttle is operating.

Jessiman, et al.[33] hypothesized several profiles for their Intercity Transportation Effectiveness Model and then checked them against actual data. This profile is a spline-fit of their profile for distances less than 500 miles and having no more than one time zone change.

The Boeing profile gave the best model calibration followed by the Intercity Transportation Effectiveness Model, Eastern Airlines Shuttle, Boeing and Port Authority of New York and New Jersey Composite, and, lastly, the Port Authority of New York and New Jersey profile.

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* While JFK is distant and has a market that is basically different from Oregon, this was the only pure third-level profile available.

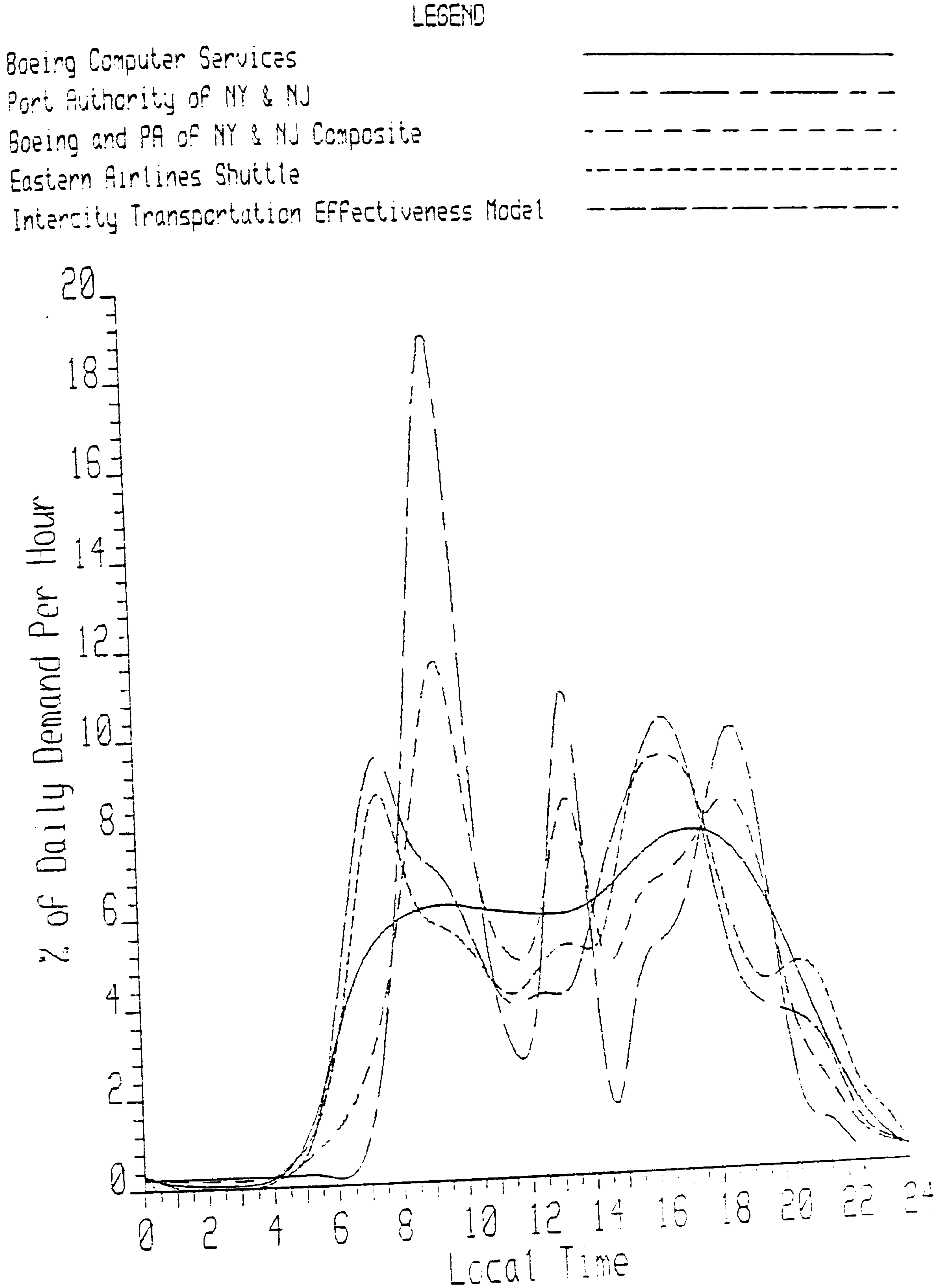


FIGURE 2-1
LOCAL DEMAND PROFILES

The demand profiles purport to represent the actual variation of demand if an infinite number of flights were available throughout the day. Under such circumstances, the frequency factor, FF, would be one. It then becomes necessary to determine what demand will be served if a finite number of flights are available at specific times throughout the day ($0 \leq FF \leq 1$).

The willingness or ability of a person to advance or delay his departure is termed his "persistence of demand." The willingness to advance or postpone a departure or arrival may vary in different circumstances, e.g., an executive going to a meeting could not postpone his departure long, but he could advance it, conversely, on returning from the meeting he could not advance his departure significantly, but he could postpone it.

It is assumed that a flight will capture the greatest fraction of a group of passengers when its departure time is ideal for those passengers. Furthermore, as the departure time moves farther and farther from the ideal time fewer and fewer of those for which the original time was ideal will select the flight. The rate and shape of traffic deterioration as a flight becomes less and less ideal for the passenger is termed the "persistence of demand function." It is assumed that the persistence of demand function is symmetrical; the rate and shape of traffic deterioration is the same for an advanced schedule or a delayed one. This may not be true, particularly early in the morning or late in the evening, as suggested above.

The rate and shape of travel demand deterioration should be based on the primary air traveler purchase--the perceived time saving. If the flight departs at the ideal time, $t = 0$, the propensity to travel should be greater than when the traveler must advance ($t < 0$), or postpone ($t > 0$), his journey. This analysis defines perceived time saving for an ideal departure as:

$$\Delta T = (DT\ \alpha) - (CI\ \beta + T_D + T_A + F_T)$$

where

ΔT is the perceived time saving with an ideal departure,

DT is the American Automobile Association driving time in hours,

α is a factor of 110% to allow for driver rest,

CI is the sum of the check-in and baggage collection time at airports of the size of interest, CI = 0.4 hours,

β is the weighting factor for nontraveling time in a trip, $\beta = 2$,34

T_D is the travel time from the air service area center to the departure airport in hours (Table 2-1),

T_A is the travel time from the arrival airport to the air service area center in hours (Table 2-1), and

FT is the flight time between airports including stops in hours.

The next requirement was to find a symmetric, nonnegative function of ΔT and t that had a value of one when the flight departed at the ideal time, t = 0, and approached zero as the departure time moved away from the ideal, $|t| \neq 0$. The persistence of demand functions tried were these:

$$F(t) = 1/2\ (\cos(\pi t/2\Delta T) + 1),\ -2\,\Delta T < t < 2\,\Delta T \qquad [1]$$

$$F(t) = 0, |t| \geq 2\,\Delta T$$

$$F(t) = 1/2\ (\cos(\pi t/\Delta T) + 1),\ -\Delta T < t < \Delta T \qquad [2]$$

$$F(t) = 0, |t| \geq \Delta T$$

The persistence of demand function, F, is the fraction of that travel demand that would have utilized the departure had the time been ideal. There are many possible functions, but only these two were tried in the model.

It was first hypothesized that when there was a time saving by air, $|t| < \Delta T$, more than half would go by air, $F > 0.5$. When there was no time advantage to either air or auto, $|t| = \Delta T$, (cost, convenience, reliability, safety, etc. being perceived as equal) half the traffic would go by air, $F = 0.5$. It was assumed that for $|t| > \Delta T$, $F < 0.5$ and when $|t| = 2\,\Delta T$, $F = 0.0$, equation [1]. This seemed logical, but it lacked explanatory power in the model. It is overly optimistic probably because, regardless of reality, cost, convenience, reliability, and safety are never perceived as being equal.

Equation [2] has the same form, but for $|t| < 1/2\,\Delta T$, $F > 0.5$, for $|t| = 1/2\Delta T$, $F = 0.5$, for $|t| > 1/2\Delta T$, $F < 0.5$ and $|t| = \Delta T$, $F = 0.0$. It gave a much better fit in the model and it agrees with the commonly accepted idea that when the perceived time saving of air travel disappears so does the air travel demand.

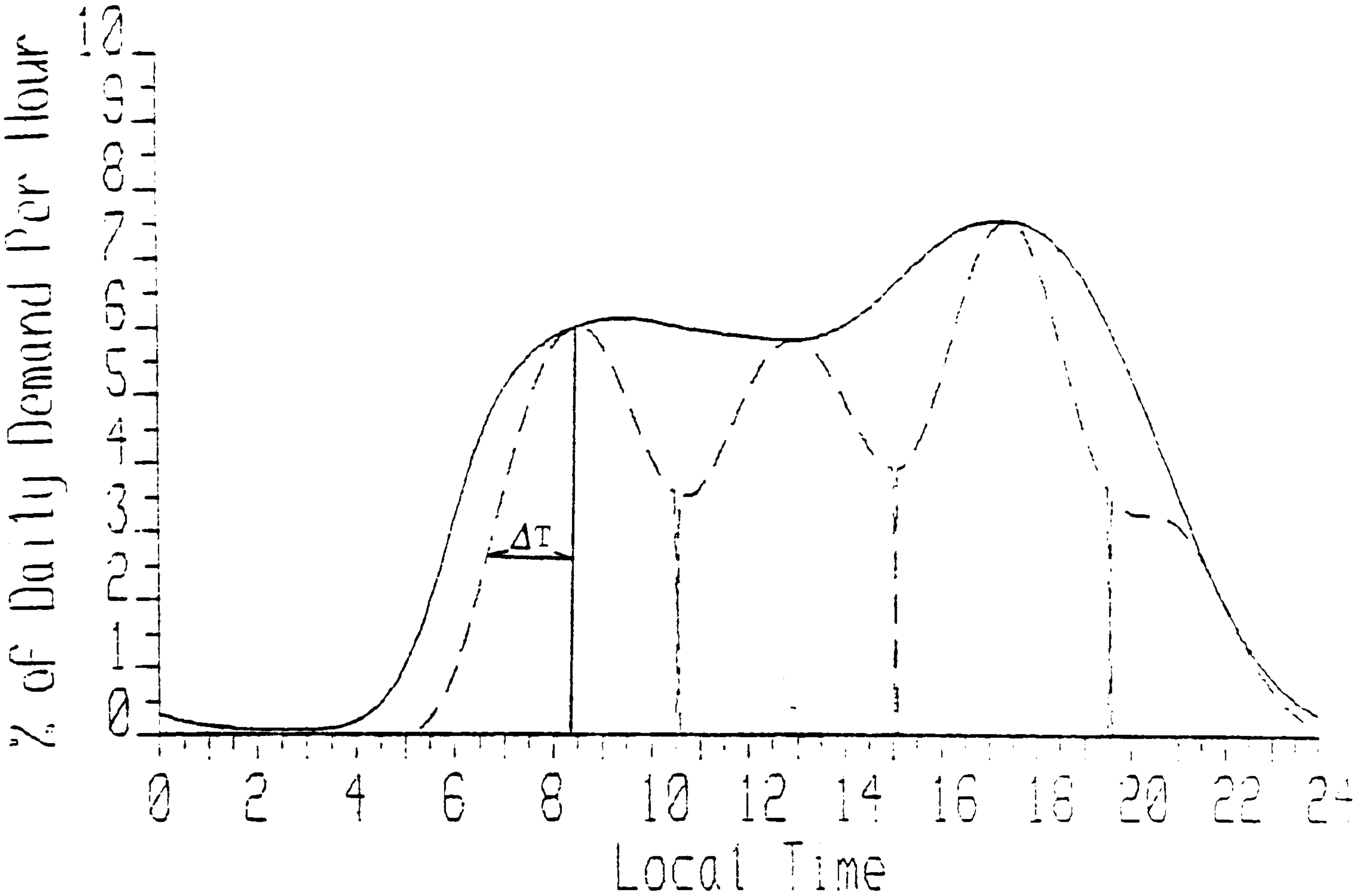
The two functions are compared in Figures 2-2A (equation [1]) and 2-2B (equation [2]). If ΔT were doubled, Figure 2-2B would look like Figure 2-2A.

Where persistence profiles overlapped they were handled as independent events, i.e., a certain percentage of those willing to advance their journey would also be among those willing to postpone it; therefore, the total travelers at time t in the overlapping portion was not:

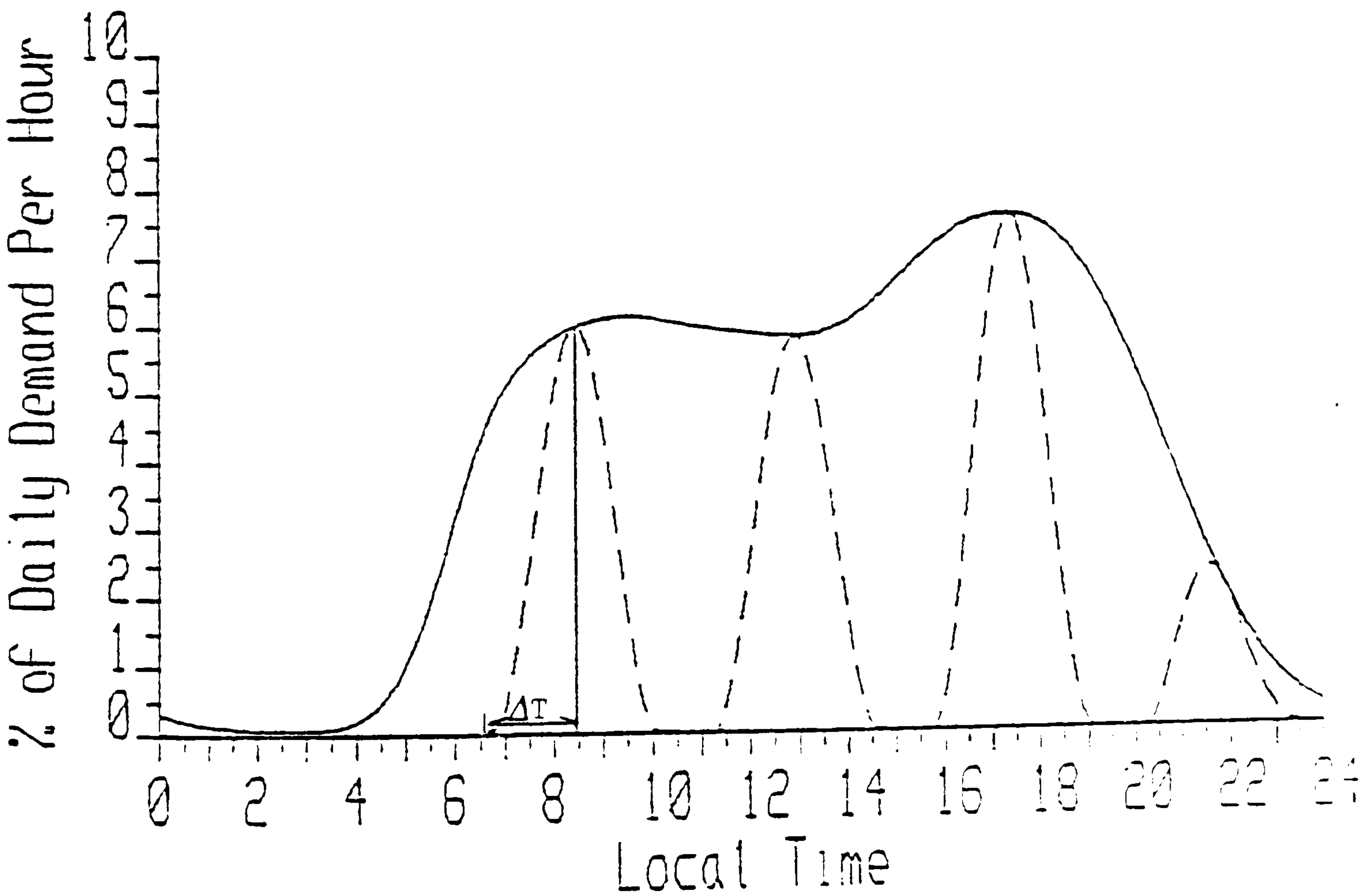
$$(F_1(t) + F_2(t))\ D(t),$$

but rather

$$(F_1(t) + F_2(t) - F_1(t)\ F_2(t))\ D(t).$$



(A)



(B)

FIGURE 2-2
DEMAND PERSISTENCE

where

> $F_1(t)$ is the value of the persistence function for the earlier departure at time t,
>
> $F_2(t)$ is the value of the persistence function for the later departure at time t, and
>
> $D(t)$ is the demand if time t were the ideal departure time.

Where t became equal to the time of another departure or $t = \Delta T$ the persistence function was set equal to zero. Rather than producing overlapping profiles the demand per flight was calculated on the cumulative persistence of demand curve midway between departures. The demand at any particular time of the day was the product of the value of the demand profile and the persistence of demand function at that time.

The frequency factor has the following desirable properties[35] (see Figures 2-2A and 2-2B):

1. As frequency, f, increases so will demand served, D,

$$\frac{\partial D}{\partial f} > 0.$$

2. As the persistence of demand functions for adjacent flights increasingly overlap, with increased flight frequency, the demand served increases at a slower rate,

$$\frac{\partial^2 D}{\partial f^2} < 0.$$

K2 (1.02396) shows that passengers vary almost directly as the frequency factor. It would be expected to be slightly greater than 1 because higher frequency factors mean more airline service and visibility. A traveler knowing a high level of air service is available, however he perceives it, will be more inclined to expect air service to be a viable alternative.

R is the reliability or the ratio of completed departures to scheduled departures. A completed departure is defined as one leaving within 15 minutes of the scheduled departure time as listed in the Official Airline Guide (OAG) regardless of the reason for the delay.

K3 (3.59346) shows the importance of schedule reliability in the intra-Oregon market. An airline offering 99% reliability can expect to receive only 96.45% of the local traffic of a 100% reliable airline. Because of the short distance and viability of other modes the passenger looks at the chances of completing a round trip as planned. With a 99% reliability each way, he only has a 98.01% chance of doing so; hence, the relatively high one-way elasticity. The round-trip elasticity with equal outbound and inbound reliability would be one-half the above.

PIM is the product of the income-weighted personal taxable income distributions multiplied by the tax return products and is defined as:

$$\left(\frac{TR_1 \left(\sum_{n=1}^{N} TR_{1n} I_n^{\gamma} \right)}{\left(\sum_{n=1}^{N} TR_{1n} I_n \right)} \right) \left(\frac{TR_2 \left(\sum_{n=1}^{N} TR_{2n} I_n^{\gamma} \right)}{\left(\sum_{n=1}^{N} TR_{2n} I_n \right)} \right) \Omega$$

where

$TR_{1 \text{ or } 2}$ is the number of tax returns from air service area 1 or 2; in this instance, 1 represents the origin and 2 represents the destination.

$TR_{1n \text{ or } 2n}$ is the number of tax returns in income range I_n from air service area 1 or 2.

I_n is the mean of the taxable income from the taxable income range n. The number of tax returns is reported for each county for standard taxable income ranges, e.g., 0 - $1500, $1500 - $3000,....,$50000+.

N is the number of taxable income ranges reported, N = 9.

γ weights the effect of income according to the level of income $\gamma = 2$ was used in this analysis as no appropriate a posteriori value could be found. While $\gamma = 2$ gave good results here, a search for a better, possibly noninteger, value of γ could provide the basis for another study. It would be expected that γ may also be inversely proportional to distance or time saving making the function nonlinear.

Ω was a scaling factor applied to make the numbers small enough for the regression program output format. Its value was 10^{-6} for travel between all Oregon cities except Portland. If Portland was either the origin or destination $\Omega = 10^{-4}$ and the right side of the above equation

$$\left(\frac{TR_2 \left(\sum_{n=1}^{N} TR_{2n} I_n^{\gamma} \right)}{\left(\sum_{n=1}^{N} TR_{2n} I_n \right)} \right)$$

was set equal to one. A dummy variable, the next independent variable to be discussed, accounted for Portland.

PIM attempts to account not only for the population, for which tax returns are an instrumental variable, and the income of the air service area, the product being the area's taxable income, but also for the effects of the distribution of income among the population. Previous studies[26,36] have suggested using only the population from households whose income exceeded $10000 for air travel forecasting. This figure could be adjusted to a real dollar value for forecasting. But another study[10] showed, in a computer sort of a transportation data tape, no significant variation in air travel in households exceeding $4000 annual disposable income; hence, this new method was developed.

This analysis showed that for every air service area, in 1975 dollars:

$$\left(\frac{\left(\sum_{n=1}^{N} TR_{1n} I_n^{\gamma}\right)}{\left(\sum_{n=1}^{N} TR_{1n} I_n\right)}\right)_{1969} > \left(\frac{\left(\sum_{n=1}^{N} TR_{1n} I_n^{\gamma}\right)}{\left(\sum_{n=1}^{N} TR_{1n} I_n\right)}\right)_{1975}$$

indicating that real income in Oregon is becoming more and more equitably distributed. This trend was extended in the forecasting.

PIM was calibrated and used in an area where population and area product were inversely proportional to the distance from the major O&D market, Portland. None of the air service areas is geographically beyond Portland. If the air service areas were situated on opposite sides of Portland, both the O&D traffic and the model would be adversely affected.

K4 (0.64479) is near to, but greater than, 0.5. This is what is generally expected for a socioeconomic variable. Traffic grows as the population and wealth of an area grow, but not as quickly.

DP is the dummy variable for Portland. This variable has value 10 when the local travel is going to Portland and 1 when the local travel involves other cities in Oregon. A similar approach was tried for Seattle and San Francisco, but neither city's data improved the statistics of the equation. Their frequency factors were so high because of large ΔTs they degraded the model; hence, their travel demand was considered connecting in nature. In practice, Seattle and San Francisco traffic would have to connect.

K5 (0.95567) has a value of 9.0296 and weights, by solution, the value of the equation where Portland is either origin or destination. Portland being the largest metropolitan area in Oregon, by a factor of 10, and the economic hub of the state, it was necessary to account for its attractiveness in intra-Oregon travel explicitly. The value, 9.0296, itself has no specific meaning.

e (2.718281828) is the base of the natural logarithm.

T is the ticket price in dollars. The fact that T is the exponent of e makes intra-Oregon air travel elasticities vary with ticket price simulating a price precipice at high prices and elasticities approaching zero at very low prices, as would be expected in practice. Various ratios and differences of ticket price and auto-trip costs, adjusted for travel group size, were tried unsuccessfully in the model.

K6 (-5.47657) the coefficient of T yields an elasticity of -1.45 at the mean ticket price of $26.444 (1975 dollars). This is in the range of -1.0 to -2.5 that should be expected.

Beta coefficients give the relative importance of the independent variables (Appendix A). The beta coefficients for the intra-Oregon travel demand model are given below.

FF - 0.73870
R - 0.25282
PIM - 0.28343
DP - 0.56833
e^T - 0.24228

Frequency factor is the most important variable and the dummy variable for Portland is second in importance. Reliability, product of the income-weighted taxable income distribution multiplied by the population products, and e to the exponent ticket price, are approximately equal in magnitude.

2.6 The Connecting Travel Demand Model

In third-level airlines 60-70% of all traffic is connecting. Thus, the most important travel model is for connecting travel. In Oregon, because the connecting traveler has a mean total trip distance of nearly 900 miles, if the traveler elects to make the trip, he most probably will make the longest segment by air. His decision to go may or may not be based on the local service offered, but his decision to use the local air service or drive to a hub airport (such as Portland) most certainly will.

The factors below were tried as independent variables, both explicitly and in appropriate combinations, in the connecting travel model:

1. Thousands of tax returns
2. Scheduled departures
3. Flight reliability
4. Average number of seats per departure
5. Time difference between ground and air modes to Portland International Airport
6. Year of the data (1969-1975)
7. Jet or nonjet service availability

8. Distance from Portland International Airport (sm)

9. Air service area mean income

10. Product of the income-weighted taxable income distributions multiplied by the population products

11. Number of nonstop destinations available

The resulting equation is given below and complete statistics are shown in Table 2-3.

$$CT/TR = K1\ CD^{K2}\ S^{K3}\ \Delta T^{K4}$$

CT/TR is the connecting traffic per thousand tax returns. It was necessary to move tax returns to the left-hand side of the equation because of its negative correlation with ΔT. Its exponent was 0.998 before the addition of ΔT so this was deemed acceptable. Income related variables had little explanatory value.

K1 (0.01877) is the calibration constant.

CD is the completed departures (scheduled departure x reliability).

K2 (0.88180) shows that travel grows more slowly than frequency. It would be expected to be greater than 1; however, the fact that it is less than 1 indicates that driving to Portland is a viable alternative.

S is the average number of seats per departure. This variable represents more than the size of the aircraft. It is also proxy for the number of destinations that can be reached nonstop from the airport, or the inverse of the system linearity from the airport, because the number of nonstop destinations are positively correlated with aircraft size. Data ranges from 8 to 120 seats per departure and from nonstop to two-stop service to the hub airport.

K3 (0.63500), as indicated above, is not only the exponent of aircraft size, but of several other system parameters as well; therefore, it cannot be precisely interpreted.

ΔT is the time difference between ground and air modes to Portland (x 10).

$$\Delta T = 10\left[(DT\ \alpha) - (CI\ \beta + T_A + FT)\right]$$

where

DT is the American Automobile Association driving time to Portland International Airport in hours,

α is a factor of 110 percent to allow for driver rest,

CI is the additional check-in time over driving to Portland, 0.2 hours,

β is the weighting factor for nontraveling time in a trip, β = 2,34

TABLE 2-3

CONNECTING TRAVEL DEMAND MODEL

LOG-LOG REGRESSION OF TOTAL CONNECTING TRAFFIC PER THOUSAND TAX RETURNS IN OREGON CITIES AGAINST NUMBER OF COMPLETED DEPARTURES PER YEAR, AVERAGE NUMBER SEATS PER AIRCRAFT AND THE DIFFERENCE IN TIME BETWEEN GROUND AND AIR MODES TO PORTLAND (HOURS X 10).

CORRELATION COEFFICIENTS

1.000	0.837	0.499	0.227
0.837	1.000	0.175	-0.053
0.499	0.175	1.000	-0.305
0.227	-0.053	-0.305	1.000

MULTIPLE REGRESSION N= 16 M= 4

VARIABLE	MEAN	ST.DEV.	CORREL.	REG.CO.	S.E. OF R.C.	COMP. T
2	7.15381	0.34992	0.83689	0.88180	0.03828	23.03751
3	4.08205	0.74952	0.49858	0.63500	0.04551	13.95178
4	3.19435	0.78809	0.22728	0.51411	0.04268	12.04568
DEPENDENT						
1	6.56730	0.96931				

INTERCEPT -3.97534 MULTIPLE CORRELN. 0.99343 S.E. OF ESTIMATE 0.12406

ANALYSIS OF VARIATION	DF	SUM SQ	MEAN SQS.	F VALUE
ATTRIB. TO REGRESSION	3	13.90877	4.63626	301.24027
DEVIATION FROM REGRESSION	12	0.18469	0.01539	

CORR. MULT. CORRELN. 0.99242
AUTO-CORRELN. OF RES. -0.18199
VON NEUMANN RATIO 2.69266
HETEROSCEDASTIC CORRELN, -0.03564
HETEROSCEDASTIC T-COMP. -0.13343

NO.	OBS.Y	EST.Y	RESIDUAL
1	7.74197	7.67199	0.06998
2	7.71431	7.76179	-0.04748
3	5.66588	5.69012	-0.02424
4	7.25340	7.27060	-0.01719
5	5.11767	5.19751	-0.07984
6	6.71195	6.61210	0.09986
7	6.85282	6.85996	-0.00714
8	7.51625	7.38117	0.13507
9	7.72222	7.91860	-0.19638
10	5.87363	5.75276	0.12087
11	7.15007	7.00098	0.14908
12	5.27763	5.39021	-0.11257
13	6.68461	6.80254	-0.11793
14	7.03425	6.98083	0.05342
15	5.64610	5.79460	-0.14849
16	5.11402	4.99102	0.12300

ORIGINAL VALUES

NO.	OBS.Y	EST.Y	RESIDUAL
1	2303.00000	2147.34271	155.65729
2	2240.16700	2349.10295	-108.93595
3	288.84100	295.92932	-7.08832
4	1412.90300	1437.40612	-24.50312
5	166.94600	180.32099	-13.87499
6	822.17400	744.04063	78.13337
7	946.54300	953.32837	-6.78537
8	1837.65600	1605.47299	232.18301
9	2257.97100	2747.91581	-489.94481
10	355.53600	315.05859	40.47741
11	1274.19400	1097.71339	176.48061
12	195.90600	219.24895	-23.34295
13	800.00000	900.13371	-100.13371
14	1134.84200	1075.81419	59.02781
15	283.18600	328.51948	-45.33348
16	166.33700	147.08641	19.25059

MEAN DEVIATION= 98.32

T_A is the time in hours required to drive from the center of the air service area to the local departure airport (Table 2-1), and

FT is the flight time to Portland International Airport in hours.

In order to achieve a good fit it was necessary to limit ΔT to a minimum value of 0.2 hours.

K4 (0.51411) is between 0.5 and 1.0 as expected and shows that connecting travel by air increases as the distance to Portland increases, but not as quickly as the difference between mode travel times, i.e., at high ΔT's there is a smaller travel increase per unit of increased travel time to Portland than at low ΔT's.

The existence of both standard class and coach fares in Oregon markets as well as the imposition of mandatory joint fares by the Domestic Passenger Fare Investigation phase 4[19] between 1969 and 1975, making 1969 and 1975 data inconsistent, made the inclusion of a price variable insignificant in the connecting travel model. Because of joint fares and the great superiority of air's quality-of-service on longer trips when compared to other modes, the explicitness of the terms in the intra-Oregon travel model did not work well for predicing connecting travel and more basic quantities performed better.

Beta coefficients for the connecting travel model are given below:

CD - 0.77319
S - 0.49101
T - 0.41799

Completed departures is the most important variable. The number of seats and the difference between ground and air modes to Portland are approximately equal.

2.6.1 North-South Connecting Travel Split

It was necessary to know what percentage of connecting traffic wanted to connect north through Portland and what percentage wanted to connect south either to or through San Francisco. I.P. Sharp's CAB data base was used in conjunction with an I.P. Sharp computer program to determine which cities Oregon passengers had connected through in the years 1973 through 1975. After the analysis it was evident which city, Portland or San Francisco, the passenger would have connected through had he been offered those alternatives.

The north-south split was not the same for all Oregon cities. As some potential cities for third-level airline service had not received air service during the data base period, it was necessary to develop a model of the north-south connecting travel split.

A regression weighted on the basis of connecting traffic in 1975 and using the official CAB distance from Portland and the official CAB distance squared as the independent variables was found to offer the best explanation of the north-south split.

$$FS = K1 - K2\ D + K3\ D^2$$

where

FS is the fraction of traffic connecting southbound,

D is the official CAB distance from Portland in statute miles,

K1 (0.785409669) is the calibration constant,

K2 (-0.001236622) is the calibration constant of distance, and

K3 (0.000004321) is the calibration constant of distance squared.

The equation represents a parabola and the t-statistics given in Table 2-4 show that confidence in it must be limited. The shortest route in Oregon is 51 sm, the route nearest the minimum of the parabola (143 sm) is 170 sm, and the longest route is 240 sm which give southbound percentages of connecting traffic of 73.36%, 70.00% and 73.85%, respectively. Hence, with a possible variation of only 3.85%, the effects of D and D^2 are not very important.

Assuming that all traffic going to northern destinations goes through Portland and all traffic going to southern destinations goes through San Francisco, the answer is what one would intuitively expect. Near to Portland there is little connecting traffic, but what exists cannot wait for a flight to Portland and drives to Portland. Hence, nearly all connecting air traffic is southbound (often for eastern destinations). At 143 sm the relative proximity of Portland to the north is influencing maximally those who are eastbound. Beyond 143 sm the greater distance of Portland and the increased proximity of San Francisco, with its greater frequency of flights, dominates the decision of those eastbound from Oregon.

2.7 The Air Freight Demand Model

The major problem with air freight estimation is that the only statistics available are for originating air freight. Air service areas the size under consideration originate approximately 30% of the freight moving through them. The remaining 70% is inbound freight when the air service areas are served by a certificated air carrier. However, when replacement service is offered by a third-level air carrier this ratio reverses with the originating freight becoming 70% and inbound freight 30%. The originating freight stays approximately constant, but the inbound air freight drops to approximately 13% of the previous level and inbound trucked freight increases accordingly for the following reasons:

1. Third-level carriers are listed in separate sections of the air freight directories which are unfamiliar to shippers and forwarders.

TABLE 2-4

CONNECTING TRAVEL SOUTHBOUND

$$FS = 0.785409669 - 0.001236622\ D + 0.000004321\ D^2$$

Sum of the Squares = 0.00021 R^2 = 0.65419

Standard Errors	t - Statistics
0.07188	10.92661
0.00103	-1.19735
0.00000	1.34740

Residues	Expected Values
0.00842	0.73358
-0.00087	0.70287
-0.04587	0.69987
0.00718	0.72382
0.02449	0.73749

Deviation from the Regression of the Sum of the Squares = 0.00593

Sum of the Errors Squared = 0.00283

2. Liability coverage may be unlisted and the shipper or forwarder lacks ICAO limited liability protection.

3. Aircraft capacities and pallet or container provisions may be unlisted.

4. Restricted article capabilities may be unlisted.

The air freight and airmail demand were originally tried as separate dependent variables, but subsequently combined because better results were obtained.

The independent variables listed below were tried either explicitly or as appropriate combinations in the air freight model.

1. Thousands of tax returns

2. Scheduled departures

3. Flight reliability

4. Product of the income-weighted taxable income distributions multiplied by the population products

5. Automobile distance from Portland

6. Annual product of the wood industry

7. Year of the data (1969 or 1976)

The resulting equation is given below and the complete statistics are shown in Table 2-5.

$$AF = K1\ TR^{K2}\ CD^{K3}$$

where

AF is the air freight and airmail in tons per year,

K1 (0.0021232) is the calibration constant,

TR is the tax returns (000's) in the air service area,

K2 (1.04147) shows that as the air service area grows in size it produces proportionately more air freight than its growth (+4.127%), but the function is weak and the relatively large standard error shows that confidence in it must be limited,

CD is the completed departures (scheduled departures x reliability), and

K3 (0.98240) shows that air freight is nearly proportional to frequency.

TABLE 2-5

AIR FREIGHT DEMAND MODEL

LOG-LOG REGRESSION OF ANNUAL AIRMAIL AND AIR FREIGHT (TONS) PER OREGON CITY AGAINST THE NUMBER OF TAX RETURNS (000'S) AND THE NUMBER OF COMPLETED DEPARTURES.

CORRELATION COEFFICIENTS

1.000	0.742	0.835
0.742	1.000	0.421
0.835	0.421	1.000

MULTIPLE REGRESSION N= 14 M= 3

VARIABLE	MEAN	ST.DEV.	CORREL.	REG.CO.	S.E. OF R.C.	COMP. T
2	3.54553	0.61396	0.74163	1.04147	0.25018	4.16288
3	7.20414	0.87264	0.83520	0.98240	0.17602	5.58120
DEPENDENT						
1	4.61433	1.34858				

INTERCEPT -6.15562 MULTIPLE CORRELN. 0.93945 S.E. OF ESTIMATE 0.50241

ANALYSIS OF VARIATION	DF	SUM SQ	MEAN SQS.	F VALUE
ATTRIB. TO REGRESSION	2	20.86633	10.43316	41.33403
DEVIATION FROM REGRESSION	11	2.77652	0.25241	

CORR. MULT. CORRELN. 0.93423
AUTO-CORRELN. OF RES. -0.04734
VON NEUMANN RATIO 2.28702
HETEROSCEDASTIC CORRELN. -0.17079
HETEROSCEDASTIC T-COMP. 2.28702

NO.	OBS.Y	EST.Y	RESIDUAL
1	6.58250	6.91435	-0.33185
2	6.14461	5.83151	0.31310
3	4.68859	4.69635	-0.00775
4	4.42017	4.04697	0.37319
5	2.09186	2.27306	-0.18120
6	3.94468	4.10108	-0.15640
7	4.08933	4.02559	0.06374
8	6.29943	6.64396	-0.34453
9	4.43046	4.23074	0.19972
10	4.53055	4.22346	0.30709
11	2.24284	3.52066	-1.27783
12	4.86753	4.34370	0.52383
13	4.36310	3.91271	0.45038
14	5.90495	5.83645	0.06850

ORIGINAL VALUES

NO.	OBS.Y	EST.Y	RESIDUAL
1	722.34000	1006.61331	-284.27331
2	466.20000	340.87450	125.32550
3	108.70000	109.54613	-0.84613
4	83.11000	57.22405	25.88595
5	8.10000	9.70906	-1.60906
6	51.66000	60.40577	-8.74577
7	59.70000	56.01346	3.68654
8	544.26000	768.13036	-223.87036
9	83.97000	68.76810	15.20190
10	92.81000	68.26946	24.54054
11	9.42000	33.80680	-24.38680
12	130.00000	76.99191	53.00809
13	78.50000	50.03460	28.46540
14	366.35000	342.56225	24.28775

MEAN DEVIATION= 60.30

K2 was expected to be somewhat larger (1.1 - 1.2) and K3 to be smaller (0.5 - 0.6). However, K3 may be indicative of prime, evening departures, suitable for overnight service in those areas receiving higher frequency. The low correlation (0.421) between TR and CD tends to confirm this possibility.

Beta coefficients for air freight demand are given below.

TR - 0.47414
CD - 0.63569

Completed departures are more important than tax returns in explaining air freight demand.

2.8 Summary of Travel Demand Models

All air travel models offer excellent explanations of the dependent variable; the corrected multiple correlation being in excess of 0.99 for both intra-Oregon and connecting travel (≅ 96% of revenue) and 0.934 for air freight (≅ 4% of revenue). The north-south traffic split model had a corrected multiple correlation of 0.734 and poor t-statistics, but the variation in the dependent variable is not very important.

The travel demand models are based on the first and last year for which data are available, 1969 and 1975. As the record period increases, the base should be broadened and, before instituting the airline, the intervening years included.

The travel demand models rely on the records of past air service in the forecast area. If there are no records of air service in an area, another method of travel demand modeling will have to be used.

3. AIRLINE COSTS

3.1 Introduction

This section reviews the methods of disaggregating airline costs, and determines the airline direct operating costs as functions of equipment and production, and indirect operating costs as functions of production.

Perhaps the most important point that can be made is that it is the effect of production on total costs rather than airline cost accounting that is important, e.g., how revenue-passenger-miles (RPM) affect total labor cost is more important than the salaries of individual positions.

3.1.1 Cost Breakdowns

There are several ways that airline costs can be broken down for analysis. The most popular method, and the main method in this study, is to divide them into direct operating costs, those cost which are attributable to the operation of aircraft, and indirect operating costs, those costs which would continue if aircraft operations ceased. But there are gray areas: landing fees, which are incremental by flight, are usually considered an indirect cost while maintenance burden and aircraft payments, neither of which cease if the aircraft aren't operated, are considered direct costs. Passenger liability insurance, usually an indirect cost, is considered a direct cost because of third-level airline industry conventions. Labor costs and nonlabor costs are natural subdivisions of both direct and indirect operating costs. This method is consistent with available data and will be developed further in the analysis.

There are other methods of cost disaggregation which deserve consideration. One method is to break costs into those which are a function of stage length and those which are not a function of stage length.

Those costs which are a function of stage length include the following:

1. Passenger handling
    a. Food and beverage service
    b. Movies, berths, etc.
2. Aircraft handling
    a. Consumable loading
    b. Preflight preparation
3. Aircraft costs
    a. Crew costs
    b. Fuel and oil

c. Maintenance labor

d. Maintenance material

e. Insurance

f. Communication

Those costs which are not a function of stage length include the following:

1. Passenger handling

   a. Reservations

   b. Tickets and waybills

   c. Check-in of passengers and cargo

2. Aircraft handling

   a. Ground equipment

   b. Ground staff

3. Aircraft cycle costs

   a. Maintenance labor

   b. Maintenance material

   c. Landing fees

The above implies that costs may be determined by the operational factors of stage length (distance) and departures (cycles). However, a closer look shows that the number of passengers is also an important determinant of both stage length and departure costs. Hence, revenue-passenger-miles (stage length x passengers) and aircraft size, implied by passengers per departure, are important indicators of production and, hence, costs.

Another method is to break costs into those an airline can affect and those which it cannot.

The airline can often affect the following:

1. Utilization of aircraft

2. Productivity of staff

3. Economics of maintenance

4. Marketing and passenger service

5. Cooperative agreements (Appendix E)

Conversely, an airline cannot normally affect the following:

1. General level of staff salaries
2. Fuel and material costs
3. Cost of stations
4. Landing fees
5. Insurance

The costs an airline can affect may determine its profitability, but will certainly determine its competitive position. The costs an airline can't affect are still subject to the pressures of competition and the pressures of the airline industry.

3.1.2 Changes in Costs Over Time

In the analysis it was necessary to take cost and revenue data from the past and project it into the future under the uncertainties of inflation. The accounting for inflation through the first quarter of 1977 used the Implicit Price Deflator for the Gross National Product (IPDGNP).[37] Six percent per year was used for the remainder of 1977 and all of 1978 as recommended by the President's Council of Economic Advisors.[38] The analysis was conducted entirely in 1978 dollars until the effects of future inflation were added in the risk analysis program (Section 6).

Labor was the major component of operating costs and was found to vary the most relative to inflation. Appendix C discusses how Standard Industrial Classification 372[39] was analyzed to get the frequency distribution of the labor cost changes relative to the IPDGNP, the weighted mean of which was found to be +1.96% per year. This agrees with the information provided by Roger J. Mallet of the Council on Wage and Price Stability.[6] It was somewhat greater than the annual rate of the Commuter Airline Association of America's (CAAA) mean salary figures which indicate a +1.26% per year real increase over the years 1972-1975.[40] The 1.96% figure was used as it provides a longer time base and has an explicit frequency distribution. Labor costs increased an average of 21.4% in real terms between the beginning of 1978 and the end of 1987.

The price changes for material goods are best represented by the Wholesale Price Index of Industrial Commodities (WPIIC).[41] The weighted mean of the WPIIC is a decrease of 0.20% per year relative to the IPDGNP. This results in a 2% decrease in real terms of nonlabor-related goods between the beginning of 1978 and the end of 1987.

3.2. Direct Operating Costs

The direct operating costs are attributable to aircraft operation and, as such, are a strong function of the aircraft and equipment selected, the way it is operated (flight planning), and maintained, and its ability to produce (payload x distance). This section discusses these items as they relate to large third-level airlines (turbine equipped).

3.2.1 Aircraft Selection

Aircraft will represent approximately 90% of a third-level airline's total investment. They will also determine the routes and stage lengths the airline can fly, the number of people or pounds of cargo that can be served per departure, the attractiveness relative to competitors, the reliability of the service, and, most important, the cost and revenue per passenger-mile or ton-mile.

The aircraft selection was done in four stages.

1. Manufacturers and operators were queried as to the day-to-day operating problems of both their own and competitors aircraft and engines.

2. An appraisal was made of where the aircraft was in its design maturity and the future product support it was likely to receive.

3. The demand equations of Section 2 were used to find feasible routes. Then it was determined which aircraft could operate them.

4. The aircraft remaining after the first three stages were compared via generalized cost equations and a single aircraft type selected.

3.2.1.1 The Operator Survey

A survey of third-level airlines and manufacturers on the equipment that they operate or manufacture is given in Table 3-1, Aircraft Advantages & Disadvantages, and Table 3-2, Engine Service Characteristics. Several items should be noted when using the tables:

1. The survey was based on ten airlines, two airframe manufacturers, one engine manufacturer, and one engine overhaul facility.

2. The level of personnel with which problems were discussed and the willingness with which they answered varied.

3. Airframes are not broken into subclassifications, e.g., B-99 vs B-99A, Twin Otter 100 vs Twin Otter 200.

4. Claims of sales brochures were disregarded unless pertinent and verified by the airlines operating the aircraft.

Perhaps the best use of the tables would be by the prospective purchaser when confronting the manufacturer. The items may have been corrected, or perhaps some solution appropriate for in-house correction developed. The data was considered too inconclusive to eliminate any aircraft at this stage of the aircraft selection process.

TABLE 3-1

AIRCRAFT ADVANTAGES AND DISADVANTAGES

Aircraft	Advantages	Disadvantages
Swearingen Metro II SA-226	Fastest viable aircraft, lowest cost per seat-mile, best system redundancy, pressurized.	Largest initial investment on available seat basis, often won't carry 19 passengers, noisy without quiet kit, tubular interior appearance, 14000 cycle limit on wing spar, hot-dimpled rivets pull through wing skin, mass flow values damaged cooling turbines in early aircraft, overvoltage protection relies on a mechanical relay, condensate forms in cockpit side windows, chined nosewheel tires require modified wheel bay, std. magnesium wheels crack--must use aluminium (a heavier, extra cost option), modification of engine cowl required for easy inspections, needs ice shields, water gets under plastic radome, generators have high maintenance requirements, door latching mechanisms a problem.
Engine	Garrett AiResearch TPE-331-303G	

TABLE 3-1
(cont'd)

AIRCRAFT ADVANTAGES AND DISADVANTAGES

Aircraft	Advantages	Disadvantages
Aerospatiale Fregate (Also NORD 262)	Largest viable aircraft, excellent airframe, pressurized.	Must be operated under FAR part 135.2, poor environmental, electrical, avionics and instrumentation systems (low TBOs), because it's out of production it requires extensive spares holdings, requires FAR part 139 airports.
Engine	Turbomeca Bastan VIIC	
Mohawk 298	New systems throughout (avionics, electrical, environmental, instrumentation), other advantages of Fregete or 262.	Most expensive, not very fast, must be operated FAR part 135.2, general availability still doubtful.
Modification of Fregate or Nord 262 by Allegheny Airlines and Frakes Aviation.		
Engine	Pratt & Whitney PT6A-45	

TABLE 3-1
(cont'd)

AIRCRAFT ADVANTAGES AND DISADVANTAGES

Aircraft	Advantages	Disadvantages
De Haviland Twin Otter -100 & -200	Low purchase price, often leasable, STOL performance.	Poor aesthetics, slow, noisy, double seats are uncomfortable and angled to longitudinal axis, 22000 cycle limit on wing, 29000 cycle wing spar mod. required, 49000 cycles must replace fuselage cradle, unpressurized, older short-nose version, -100, is ten knots faster than -200.
Engine	Pratt & Whitney PT6A-27	
Beech 99 & 99A	Low purchase price, excellent dealer network.	Spar cap required every 10000 hours, early systems problems, unpressurized, production currently suspended.
Engine	Pratt & Whitney PT6A-20 (99) PT6A-27 (99A)	
Handley Page Jetstream	Stand-up headroom, pressurized, with increased gross weight and fuselage plug could be best 19-passenger airframe.	Poor engine TBOs; air pressurization turbines, electrical system, and cockpit all need redesign, starter-generator should have been alternator with larger starter, poor support in U. S. (1 operator), currently out of production.
Engine	Turbomeca Astazou XIV or XVI	

TABLE 3-1
(concl'd)

AIRCRAFT ADVANTAGES AND DISADVANTAGES

Aircraft	Advantages	Disadvantages
Short Bros. & Harland Skyvan	Good cargo facilities.	Poor aesthetics slow, noisy, unpressurized, leading edges of wing struts and main gear fairings crack, exposed nylon rollers of torque-tube flight controls wear out.
Engine	PT6A-27	
Short Bros. & Harland SD 3-30	Good Cargo facilities, good headroom, toilet.	Poor aesthetics, slow, unpressurized, insufficient operating experience.
Engine	Pratt & Whitney PT6A-45	
Embraer Bandeirante EMB-110		Unpressurized, uncertificated in U. S. at present.
Engine	Pratt & Whitney PT6A-27	

TABLE 3-2

ENGINE SERVICE CHARACTERISTICS

Engine	Service Characteristics
Garrett AiResearch TPE - 331-303G	Engine Time-Between-Overhaul (TBO): 6000 hours Hot-Section Inspection: 2000 hours Fuel Pump & Fuel Control TBO: 4000 hours Mean-Time-Between-Unscheduled-Removals: 4217 hours
Pratt & Whitney PT6A-20 or -27	Engine TBO: 3500 - 8600 hours Hot-Section Inspection: 2500 cycles Early stage compressor blade wear. Must wash compressor blades to get rid of salt and other deposits as engine won't ingest rain (or ice).
Pratt & Whitney PT6A-45	Engine TBO: 1500 hours (expected to rise shortly to 3000 hours) Other characteristics similar to -27.
Turbomeca Bastan VIIC	Engine TBO: 7000 hours Hot-Section Inspection: 3600 hours or 3250 cycles Prop TBO: 2750 hours Engine must be overhauled by operator as overhaul by French exceeds 6 months.
Turbomeca Astazou XIV	Engine TBO: 800 hours
Turbomeca Astazou XVI	Engine TBO: 1200 hours

3.2.1.2 Design Maturity

The costs associated with aircraft ownership can vary throughout the life of the aircraft. A component, system or, presumably, the whole aircraft over its life may absorb up to three times its initial purchase price in maintenance. Unscheduled maintenance for some components may drop to 15% of the initial rate, man-hours per flight-hour may drop to 30% of the initial time required, and check cycles may lengthen to 300% of the initial time. An operator can expect 67% of the service bulletins to be issued in the first four years after certification and about 3% per year thereafter.[42] Dispatch reliability and as much as half of all maintenance costs may be attributed to engineering design; basic design changes are required to alter them. Lastly, regardless of the manufacturer's claims, the government will require a lot of expensive checks for a long time on a new design.[43]

Third-level operators have come to realize that cost-effectiveness is no longer initial investment, but total cost: initial investment, spares investment, dispatch reliability, failure rate, downtime, labor to repair, labor to test or inspect, paperwork, and the tradeoff between system safety through redundancy and additional maintenance requirements. Therefore, a period of time must transpire before any accurate appraisal can be made as to the cost-effectiveness of a new design.

An attempt was made to apply these criteria to the aircraft being evaluated. It lead to three classifications: too new, out-of-production, and acceptable.

The Embraer Bandierante has not had sufficient time for cost-effectiveness appraisal. Currently, it is uncertificated and unsupported in the United States.

The Short Brothers & Harland SD-3-30 would also fail under this criterion, but Shorts' has the Skyvan which has a good record of support and some airframe and system commonality. The aircraft is certificated and supported in the U.S.

The Handley-Page Jetstream is at the other end of the spectrum. It is currently out of production and unsupported in the U.S. Its engines, even the Astazou XVI, keep it from being a serious contender as an airliner. This is unfortunate as it is the only aircraft under 20 seats with stand-up headroom. It would have to be operated over 12500 pounds GTOW under FAR part 135.2 (FAR part 121 maintenance standards) to take full advantage of its capabilities.

The Beech 99 and 99A are also out of production at the present time. But they still compose a significant portion of the third-level fleet. The B-99(A) would have to be purchased or leased as a used aircraft and this could create problems of commonality of maintenance, modifications, and equipment.

The Aerospatiale Fregate or Nord 262 is out of production, but still in use by three U. S. airlines. The Mohawk 298 uses this airframe, but the systems and engines are new or used on other aircraft. Because of the prospect of the revival of the airframe by the French, under the urging of Allegheny Airlines and Frakes Aviation, the Mohawk 298 was not eliminated from consideration.

The Swearingen Metroliner II (Metro or Metro II) has been in production for over six years and its rate of production is scheduled to increase in the near future to 3 units per month.

3.2.1.3 Feasible Routes

The routes offering initial feasibility are shown in Figure 3-1. The Minimum-En-Route-Altitudes (MEAs) are also given. The MEAs are high, particularly in the eastern half of the state.

Longer air routes in the eastern half of the state could be flown with unpressurized aircraft and the high MEAs avoided. Unpressurized aircraft are slower than pressurized aircraft. They would only lengthen travel time in aircraft types lacking many airliner conveniences, e.g., refreshments, toilets. Pressurized aircraft, by virtue of their size and speed, offer more passenger comfort and better seat-mile costs than slower, cheaper unpressurized aircraft, despite their higher purchase price.

It is proposed to use Medford, a small hub, as a collection point for southbound connecting traffic. Medford does not have radar, but it can still handle an IFR arrival every two minutes.[44] The lowest altitude at which the highest aircraft could arrive is 11000 feet MSL and it should be on the ground, 1300 feet MSL, in 10 minutes. This results in an excessive rate of descent, 970 feet per minute, for an unpressurized aircraft. The alternative is longer delays on arrival at Medford, which would decrease demand.

It was decided to limit the analysis to pressurized aircraft. This eliminated the De Haviland Twin Otter, and Shorts Skyvan and SD 3-30. The choice was, therefore, between the Mohawk 298 and the Swearingen Metroliner II.

3.2.2 Aircraft Purchase Price and Annual Cost

It was necessary to develop the purchase price of the Swearingen Metro II and Mohawk 298 in different ways. The cost of the Metro II, its options, and recommended spares can be obtained from the manufacturer. The cost of the Mohawk 298 is the sum of the cost of a used Aerospatiale Fregate or Nord 262 airframe plus the cost of conversion as estimated by the converters. Options are limited to what the aircraft had on it before conversion and to what is available from airlines, suppliers, and the manufacturer's unsold stock. Airframe spares that cannot be fabricated in the airline shop are similarly limited. One other source of spares is to buy extra used aircraft.

When equipping with an out-of-production aircraft the spares provisioning policy must differ from that of a production aircraft. With a production aircraft, the policy should be to purchase a wide range of items to a minimum depth pending an operational exploration of needs. With an out-of-production aircraft, it is necessary to initially purchase all spares, or ensure in some other way, that spares will be available for the planned life of the aircraft.

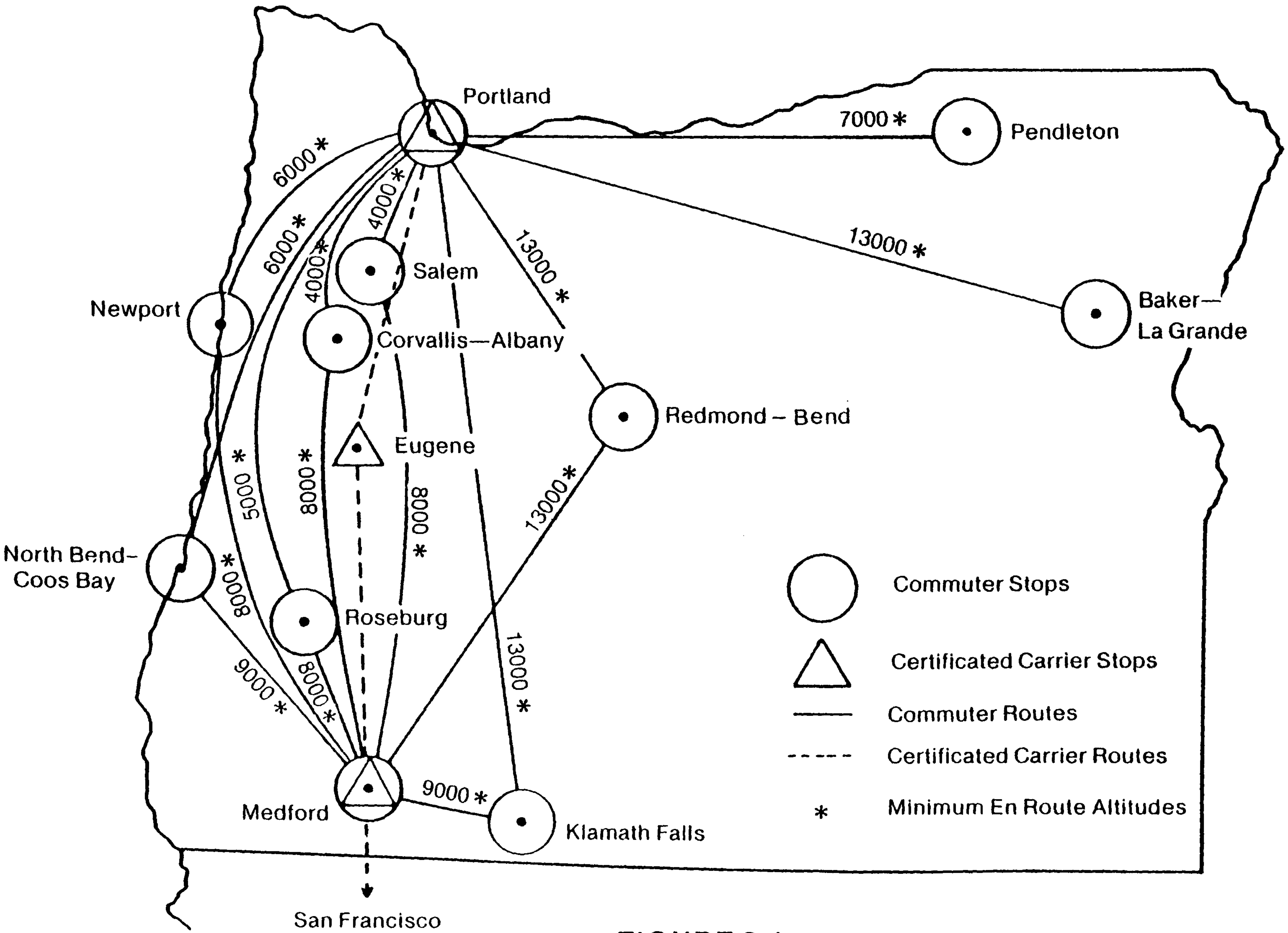


FIGURE 3-1
FEASIBLE OREGON ROUTES

The Mohawk 298 will need out-of-production spares levels for the airframe only. Systems and engines are new and supportable. Still, more spares will be needed initially for the Mohawk 298 than the Swearingen Metro II. The required initial airframe spares were found to amount to $192000 for each additional Mohawk 298. Such a large initial investment in spares for the Mohawk 298 allows hourly airframe material costs to be reduced by 22.4%.

The cost of the next aircraft for both aircraft types is shown in Table 3-3. Swearingen would offer a 10% discount on the list price for orders of four or more aircraft. The consensus of airlines and manufacturers is that list price and purchase price varies little in the third-level market unless large orders (≥4) are placed.

The annual aircraft cost, based on outright purchase for the Swearingen Metro II is $112397 (Table 3-4). The annual aircraft cost for the Mohawk 298 was found to be $188228 by the same method. This initial analysis is based on aircraft purchase. Different methods of finance are considered later.[45]

For tax purposes, the aircraft are depreciated over seven years by the sum-of-the-years'-digits method to a 15% residual. This gives the maximum net-present-value (NPV) for any discount rate from 1-20% for a period of six or more years by allowing use of tax benefits as early as possible. (If unused, tax benefits may be carried forward.)

In real terms, an aircraft of this type loses approximately 8% of its value when it is first sold and then depreciates to about 30% of its original value (in constant dollars) over a nine- to ten-year time period.[46]

When the aircraft is resold in inflated dollars, it will normally bring 40% of its purchase price. A capital gains tax of 50% must be paid on the amount exeeding the depreciated value.

3.2.2.1 Airframe Options

This section discusses the airframe options for the Metro II listed in Table 3-5.

Alumigrip paint was added to the fuselage and vertical tail. The standard paint scheme leaves these areas as bare metal. A fully painted aircraft is preferable because of the coastal area of operations and the 70 inches of annual rainfall in the western half of the state. Polyurethane paint, which is not offered, would be preferable to Alumigrip as it is more flexible and offers better seam-sealing properties. The rain erosion kit is practical for the same reason.

The antenna package is required for the radios purchased as is flux-valve wiring for the gyrosyn compasses.

The invermotor boost pumps are reputed to have four times the Mean-Time-Between-Failure (MTBF) of the standard pumps.

TABLE 3-3

COST OF THE NEXT AIRCRAFT

Cost of Next Swearingen Metro II

Airframe	941700		
Airframe Options	27600		
Avionics	97236		
Airframe Spares	+ 8000		

List Price	1074536		
10% Discount	- 107454		

		967082	
Engine Spares			
Engine Cost	103594		
Fraction Per Aircraft	X 0.5		

Spare Engine Cost Per Aircraft		+ 51797	

TOTAL COST			1018879

Cost of Next Mohawk 298

Converted Airframe (Estimated)	1300000		
Avionics	97236		
Airframe Spares (Estimated)	+ 192000		

		1589236	
Engine Spares			
Engine Cost	92000		
Fraction Per Aircraft	X 0.5		

Spare Engine Cost Per Aircraft		+ 46000	

TOTAL COST			1635236

TABLE 3-4

ANNUAL SWEARINGEN METRO II COST

ASSUMPTIONS

Project Life	:	10 Years
Cost of Capital	:	13%
Depreciation	:	Sum-of-the-Years'-Digits, 7 years
Residual	:	10%
Resale Value	:	30%
Investment Tax Credit (ITC)	:	10%
Effective Tax Rate	:	52%
Capital Gains Tax Rate	:	50%
Cost of Aircraft Equipped	:	$959882
Cost of Spares	:	$58997

PRECALCULATIONS

Cumulative Present Value Factor, 10 years @ 13%	:	5.426
Present Value Factor, 10 Years @ 13%	:	0.2946
Net-Present-Value of Depreciation	:	0.7081
Depreciable Portion of Aircraft (100% - 10%)	:	90%
Taxable Capital Gains on Aircraft (30% - 10%)	:	20%

CALCULATIONS

AIRCRAFT AND SPARES			
Aircraft Cost	959882		
Cost of Spares	+ 58997		

Purchase Cost		1018879	
STOCKHOLDING COSTS			
Stock Cost	58997		
Stockholding Rate	X 0.08		

Stockholding Cost	4720		
Cum PV Factor	X 5.426		

PV of Stockholding		+ 25611	

PV of Aircraft Cost			(1044490)

TABLE 3-4
(cont'd)

ANNUAL SWEARINGEN METRO II COST

TAX CREDITS		
INVESTMENT TAX CREDIT		
Purchase Cost	1018879	
ITC Rate	X 0.10	

Investment Tax Credit		101889
DEPRECIATION		
Purchase Cost	1018879	
Depreciable Fraction	X 0.90	

Depreciable Amount	916991	
Dep PV Factor	X 0.7081	

PV of Deprec. Before Tax	649298	
Tax Rate	X 0.52	

PV of Depreciation After Tax		337635
RESIDUAL VALUE		
Purchase Cost	1018879	
Residual	X 0.10	

Residual Value	101888	
PV Factor	X 0.2946	

PV of Residual		30016

TABLE 3-4
(concl'd)

ANNUAL SWEARINGEN METRO II COST

CAPITAL GAINS			
Purchase Cost	1018879		
Fraction Subject To Tax	X 0.20		

Gain Taxed	203776		
Retention Rate	X 0.50		

After Tax Savings	101888		
PV Factor	X 0.2946		

PV of Capital Gain		+ 30016	

PV of Tax Credits			+499556

NET-PRESENT-VALUE OF AIRCRAFT OWNERSHIP			(544934)
ANNUAL VALUE OF AIRCRAFT OWNERSHIP			
Net-Present-Value of Aircraft Ownership			(544934)
Cum PV Factor			÷5.426

ANNUAL VALUE OF AIRCRAFT OWNERSHIP			(100430)

TABLE 3-5

SWEARINGEN METRO II OPTIONS

Item	Weight (Pounds)	Cost ($)
Alumigrip Paint on Fuselage and Vertical Tail	8.0	1500
Antenna Package	14.0	1400
Invermotor Boost Pumps (4)	0.0	6200
Flux-Valve Wiring--Left Wing and Tail	3.0	500
Magnasticks--External Fuel Gauges	3.0	660
Rain Erosion Prevention Kit	3.0	660
Remote Cabin Temperature Indicator	2.0	220
Strobe Lights--Whelan	5.0	1800
Engine Fire Extinguishers	23.0	6580
Aluminum Main Wheels	7.0	1640
Oxygen Bottle--115 cu. ft.	23.0	300
Environmental Protection Agency Kit	4.5	2200
Aeromat in Nose Baggage Compartment	8.0	160
Acoustic Windows--Cockpit Only	6.0	400
Cockpit Storage Pockets	0.0	100
Supersound Proofing	30.0	2440
Clip-On Sun Visors on Wrap-Around Track	2.0	220
Cargo Door Latch Windows	1.0	360
Cargo Tie-Down Net	+ 0.0	+ 260
TOTAL	142.5	$27600

Fueling will be required at every station if a near-capacity load is carried. External fuel guages will eliminate the need for a crew member or line boy in the cockpit.

The engine fire extinguishes are not required. The manufacturer does not recommend them because of the weight and, he claims, the engine firewall will stop all fires. On the other hand, most of the flying will be over mountainous forests where an emergency landing at the landing speeds required would be unsurvivable. It was decided to add fire extinguishers despite the weight penalty.

Strobe lights are included as both a day and night safety item that is standard in the industry on this size aircraft.

Aluminum main wheels are a necessary, extra cost option because the standard, lighter magnesium wheels have a high failure rate.

The Environmental Protection Agency kit is required by the government.

Supplemental oxygen for the crew is required because of the high MEAs over the mountains and at the planned altitudes over other routes where descents may be prohibited by traffic.

Cargo door latch windows are necessary because the Metro II carries fuselage loads through the doors rather than around them; therefore, a definitive check is required.

The cargo tie-down net is a standard item that costs extra.

The remote cabin temperature indicator, acoustic cockpit windows, Aeromat in the nose compartment, and super soundproofing are all controversial items because of their weight (46 pounds total). The Aeromat and acoustic cockpit windows are particularly unnecessary according to the manufacturer. The manufacturer maintains that the crew is paid to endure the noise. They are retained anyway; one of the disadvantages of the Metro II is its noise level.

Clip-on sunvisors should be standard on this size aircraft.

3.2.3 Avionics Selection

Avionics can constitute from 5% to 20% of the price of a third-level airliner so an analysis of avionics is required.

3.2.3.1 Introduction to Avionics

There are three types of avionics available. The first is non-Technical Standard Ordered (nonTSO'd), panel mounted, used in single-engine light aircraft or older twins, and the cheapest. It meets Federal Communications Commission (FCC) specifications, but no FAA specifications other than as required by FAR part 91. Next is TSO'd equipment which meets FAA "minimum performance and quality control standards for specified materials, parts or applicances used on civil aircraft," as set forth in FAR part 37. The technical standards, such as electromagnetic interference (EMI), radio frequency interference

(RFI), and spurious emissions (SPURS), are set by the Radio Technical Commission for Aeronautics (RTCA) and meet all FAA and FCC standards. The manufacturer is required to file schematics and other design drawings with the FAA and to label the equipment with the: name and address of the manufacturer; name, type, or model designation; nominal weight (the greater of 0.2 pounds or 3%, but not to exceed 10 pounds); serial number or date of manufacture; and applicable TSO number. TSO'd-only equipment is normally panel mounted. In addition to TSO-ing equipment, the manufacturer may certify the equipment in those environmental categories, abbreviated "Env. Cat.", for which the equipment is designed. Each separate component, antenna, receiver, indicator, etc., must be identified with the name of the manufacturer, TSO number, and environmental categories for which the component is certified. The environmental categories are listed in order below:

1. Temperature-altitude
2. Humidity
3. Vibration
4. Audio frequency magnetic field susceptibility
5. Radio frequency susceptibility
6. Emission of spurious radio frequency energy
7. Explosion category
8. Waterproofness
9. Hydraulic fluid
10. Sand and dust
11. Fungus resistance
12. Salt spray

The article must be marked to indicate the class of centering accuracy (class A (best), B, C, or D (worst)) for which it is designed. Where an environmental test is not applicable or conducted, an "X" is placed in that column. If equipment is certified in more than one class for a specific category, the manufacturer places one class over the other in the column. At the end of environmental categories may come a "Class I, II, III" or "Class A, B" which indicates a special performance parameter applicable only to that type of equipment. The following is a typical environmental category marking:

Env. Cat. $\frac{A}{D}$ A B A A A X X X X X Class I

TSO'd equipment with environmental category certification is remotely mounted.

The third type of equipment is generally referred to as "ARINC" equipment after Aeronautical Radio Incorporated. The packaging and interfacing is specified by the Airlines Electronic Engineering Committee (AEEC), a subcommittee of ARINC. The container size is standardized for attachments and size in terms of ATRs (originally standing for Austin-Trumbull Rack, but now corrupted to "Air Transport Radio"). While this is the best equipment available, its weight limits application to aircraft of 20000 pounds or more.

3.2.3.2 Design of Avionics Installations

The design of avionic installations should consider the following:

1. Functional requirements
2. Aircraft performance capabilities
3. Space availability
4. Weight effectiveness
5. Pilot workload requirements
6. State-of-the-art interfacing
7. Serviceability
8. Cost effectiveness

All equipment should meet the following environmental categories for third-level operations:

Env. Cat. A or B A A A B B X X X X X X (applicable special class)

A is to be preferred in all categories. In the temperature-altitude category A or B classificaton is suitable. B is full certification to 30000 feet and third-level aircraft aren't presently used above 25000 feet. Humidity is either A or not tested, X, therefore, A is required.

Because of the low wing-loading, steep lift-curve slope, and relatively high CAS in cruise, category A is applicable for shock and vibration. Audio frequency magnetic field susceptibility requires A because the AC electrical system exceeds 250 VA. Radio frequency susceptibility test (radiated and conducted) could be B as the aircraft is equal to or less than 12500 pounds.

B is satisfactory for emissions of spurious radio frequency energy. Categories 7-12 do not apply to avionics. Equipment TSO numbers and special applicable classes are given in Table 3-6.

Equipment used in third-level service is often panel mounted and TSO'd, but does not meet environmental category standards. Operators often choose this equipment because they have grown from a Fixed-Base Operator (FBO) into the third-level market and have had excellent results with this equipment in smaller aircraft. Secondly, this

TABLE 3-6

APPLICABLE TECHNICAL STANDARD ORDERS AND SPECIAL CLASSES

VOR Navigation (VOR):	TSO-C40A
VHF Communications (COMM):	TSO-C37B Class I (200 NM, > 16 Watts)
Radio Magnetic Indicator (RMI):	TSO-C6C
Marker Beacon (MKR):	TSO-C35D Class A (both en route & approach)
Glide Slope (GS):	TSO-C34C
Localizer (LOC):	TSO-C36C
Automation Direction Finder (ADF):	TSO-C41A Class A (all frequencies)
Distance Measuring Equipment (DME):	TSO-C66A
Radar:	TSO-C63B Class III or greater (> 75 NM range)
Transponder (XPDR):	TSO-C74B Class I (> 15000 ft)
Radar Altimeter:	TSO-C67 or C87
Reporting Altimeter:	TSO-C88
Audio Amplifier	TSO-C50B

equipment is recommended by the manufacturers of gross-weight limited aircraft because of the wire weight savings of 30 pounds or more with panel-mounted equipment. The problem is that equipment that appears reliable in aircraft operating 800-1000 hours per year may appear unreliable in aircraft that are operated 3000 hours per year, even though the Mean-Time-Between-Failure (MTBF) is identical. Panel-mounted equipment is less reliable because the panel is a hot area which is detrimental to solid-state electronics; MTBFs are often doubled by moving the same circuits off the panel. Third-level airlines have discovered these problems and are upgrading from panel-mounted avionics.

The type of equipment anticipated has MTBFs similar to ARINC equipment, except for pulse equipment which is slightly worse (Transponder, Radar, DME). The Mean-Time-Between-Unscheduled-Removals (MTBUR) are actually better than ARINC equipment because of the lack of self-test and monitor functions, which may give erroneous indications. Also, the lack of standardization requirements permits manufacturers to utilize the latest techniques.

3.2.3.3 Selection of Avionics

The criterion is that equipment which meets applicable TSOs and Env. Cats. should be duplicated when it is essential to flight (Comm, VOR, RMI, MKR, LOC, GS, and Audio Amplifier) and not duplicated if it is not normally essential to flight safety (ADF, XPDR, Radar, DME, Radar Altimeter, and Reporting Altimeter).

The equipment selected is the Collins "Pro-line," a remote-mounted package meeting all TSO and Env. Cat. requirements; only the HSI and RMI are not wholly solid-state in this package. It is offered as a factory-installed option.

The airframe manufacturer's packages did not allow a specific item-by-item breakdown of selected equipment. To do the breakdown from the avionics manufacturer's list would leave out items necessary to this particular aircraft. The equipment is listed in Table 3-7.

Nothing was specifically done regarding antennae because the airframe manufacturer has an antenna pack meeting the United Kingdom's Civil Aviation Authority requirements. The U.S. does not have an antenna standard for this type aircraft.

The total weight of this package is 194 pounds installed and the cost is $97236 before discounts. The power requirement is 18.1 amperes when receiving and 26.9 amperes when transmitting.

3.2.3.4 Radar and Autopilots

Radar and autopilots deserve special consideration.

The primary reason for passenger discomfort, both mental and physical, is turbulence. Therefore, avoiding turbulence should be a primary operating consideration. It is possible to avoid major areas of orographic turbulence through the use of charts. Clear air turbulence associated with jetstreams may be forecast with a knowledge of shear

TABLE 3-7

AVIONICS EQUIPMENT

VHF Communications
Dual Collins VHF-20 Transceivers with dual Gables controls on No. 1 system and a single Gables control on No. 2 system.

VOR Navigation
Dual Collins VIR-30A VOR/LOC receivers with glideslope, marker beacon and 50 KHZ spacing, dual 331H-3G VOR/ILS indicators, Gables controls.

Radio Direction Finder
One Collins ADF-60B with 614L-11 Control and dual Collins 332C-10 RMI's with dual needles.

ATC Transponder
One Collins TDR-90 transponder with a Gables control.

Distance Measuring Equipment
One Collins DME-40 digital display DME channeled with Nav 1, Nav 2, or last selected frequency. Dual readouts.

Radar Altimeter
One Collins ALT-55A with dual readouts.

Downed Aircraft Locator
One GML Rescue 88 downed aircraft locator.

Audio
Dual Collins 356F-3 audio amplifiers and 356C-4 isolation amplifiers, custom audio panels and cabin page. Dual voice/range filters, dual lightweight boom mike headsets with push button switches on control wheels, dual hand mikes, and dual cockpit speakers.

Horizontal Situation Indicators (HSI)
Dual Collins PN-101 compass systems with displays.

Radar
One Collins WXR-250 digitalized 300 NM weather radar with 18" phrase-arrayed, flat-plate antenna, with Collins 332D-11A stabilization system.

Antenna Package
Standard Swearingen antenna pack using Collins antennae with U.K. certified polar diagrams.

rates adjacent to the jetstream. Radar can detect steep rainfall gradients which are associated with the vertical gusts (turbulence) occuring in thunderstorms. (A thunderstorm is defined as a cumulonimbus that has built vertically through the -20°C isotherm enabling lightning and, hence, thunder to develop.)

Operators of jet transport equipment use radar to detect and avoid thunderstorms. Jet transports have high wing-loadings of up to 155 pounds per square foot and relatively low lift-curve slopes because of a high wing sweep which results in an elastic-axis ahead of the center of lift on a flexible (span-wise and torsionally) wing. These factors tend to make for a soft ride.

Cumulonimbus that are not thunderstorms may still have significant shear areas, particularly as regards passenger comfort in third-level equipment. Aircraft in third-level service have low wing-loadings of 35 to 45 pounds per square foot and unswept, rigid wings that have high lift-curve slopes. This gives a relatively hard ride. Therefore, a third-level operator may be justified in selecting radar even though few thunderstorms occur throughout the area of operations.*

In the past third-level operators have been reluctant to include weather radar in their avionics packages for three reasons:

1. Initial investment is quite high, $7000 - $22000 installed.

2. Late 1960s radars approached 60 pounds which was a serious consideration on a gross-weight-limited aircraft, but radar weights are now as low as 22 pounds.

3. Early tube (valve)-type radars were very high maintenance items.

This attitude is changing. With passengers requiring comfort to major airline standards and new technology offering lower initial investment, light weight, and higher MTBFs, radar is being added to third-level airline fleets.

Autopilots have been, and continue to be, rejected by operators on the basis of:

1. Low utilization, because of relatively low crew workload, because of crew preference for hand-flown approaches, and because of little opportunity for en route use with short stage lengths.

2. High initial investment, $23000 - $35000, though with a Horizontal Situation Indicator (HSI) already installed costs may be $5000 less.

3. High weight, 70-85 pounds, which may be reduced by 10 pounds if an HSI is already installed.

---

* Weather radar has been required on third-level aircraft since December 1, 1979 (FAR 135.175).

4. High maintenance costs, because many of the suitable autopilots still have tube (valve) components with relatively high failure and heat output which is detrimental to solid-state equipment. The gyros also have low MTBFs and high repair costs.

3.2.3.5 Avionics Spares

Avionics spares are not considered variable over the small range of fleet size anticipated. Spares are one complete set for an aircraft plus an extra navigation radio and horizontal situation indicator, but minus one distance measuring equipment indicator, one radar altimeter indicator, and one communications tuning head. Spares value is $106597 before discounts.

3.2.3.6 Avionics Warranties

Collins offers a 12 month parts and labor warranty from the "in service" date on the Pro-Line, but a large operator should be able to arrange better terms. One manufacturer, Lockheed, on the L-1011, recently required the following avionics system guarantees:

1. MTBF

2. MTBUR

3. Maintenance cost per unit of productivity

4. Dispatch reliability--the system could not delay the aircraft more than 15 minutes

It is doubtful that a third-level operator could get such guarantees on systems, but the operator should be able to get them on system components. It should be noted that actual MTBFs and MTBURs are approximately two-thirds of the design values at any stage of component development.

3.2.4 Flight Planning

Perhaps the most important policy that a third-level airline can pursue is to file Visual Flight Rules (VFR) and go direct whenever possible, saving time and adding payload (smaller fuel reserve requirement). The "U.S. Naval Weather Service World-Wide Airfield Summaries"[47] were used to determine the likelihood of Instrument Meteorological Conditions (IMC) necessitating flight by Instrument Flight Rules (IFR). An instrument flight is presumed when the ceiling is less than 10000 feet and the visibility less than 3 miles. This is a very conservative approach, but it is necessary to translate reported observations, the records of which are available, into forecasts, which are not available, that ensure an instrument approach will not be required from two hours before until two hours after the planned arrival time. Systemwide the airline would be required to carry IFR alternate fuel and IFR fuel reserves 38% of the time.

Distances and courses are taken from Jeppesen's "Low Altitude En Route Chart - 2" along the route most likely to be assigned by the Seattle Air Route Traffic Control Center or Portland Approach Control.[48]

3.2.4.1 Altitudes and Temperatures for Take-off and Landing

The temperature criterion for take-off flight planning was that 85% of all daily maximum temperatures for the hottest month of the year be below this value.[49] Klamath Falls has an 85% temperature of 38°C which restricts the second-segment climb performance of the Metro II and, hence, limits its take-off weight to 11600 pounds. No other airports were Weight-Altitude-Temperature (WAT) limited.

Under the limiting conditions at Klamath Falls, the Metro II has an "accelerate and slow to 35 knots" distance of 5400 feet using normal procedures and 3400 feet using short-field procedures. The 3400 foot distance is less than any runway on the route. (The concept of "accelerate and slow to 35 knots" is ridiculous, regardless of compatibility with SFAR part 23.)

3.2.4.2 Temperatures for Economics and Scheduling

The temperatures for economics are the route yearly averages, International Standard Atmosphere (ISA) + 5°C in this instance. The temperatures for scheduling can either be the 85% temperature aloft (temperature that is exceeded only 15% of the time) or ISA+15°C which is used because it is more conservative (the 85% temperature is 14°C)[49] and readily available from the aircraft performance charts. The optimum route altitude can be used for economics and scheduling as the altitude does not significantly change flight times or fuel usage when the following equation is used.

Optimum Altitude = 16000' - ($\pm$ difference from ISA in °C)(200')

Therefore,

$$\text{ISA} + 5^{\circ}\text{C} = 15000 \text{ feet, and}$$

$$\text{ISA} + 15^{\circ}\text{C} = 13000 \text{ feet.}$$

3.2.4.3 Winds for Economics and Scheduling

There are two different methods recommended for taking winds into account for economics and scheduling. Williams[48] recommends using 50% of the mean scalar wind for economics and 85% of the mean scalar wind for schedule planning, both as headwind components. George[50] recommends using the mean vector wind for economics and the appropriate number of windspeed standard deviations for the scheduling accuracy desired. George's method is more accurate and is easily used for the economic portion since the mean vector wind is readily available. The problem with the flight scheduling portion is that only the circular standard deviation is available; this contains no directional information and, hence, where wind deviations are strongly directional, accuracy is a problem. What is needed is an ellipsoidal distribution. This would contain directional information that could be differentiated for a maximum headwind standard deviation and then used for scheduling. Routes being considered lie along the west coast in the mid-latitudes where prevailing westerlies are strong; therefore, the distributions may be assumed circular with no real loss of accuracy.[51]

The yearly mean wind vector is used to determine economics. The mean wind for economics at 15000 feet is 21 mph from 285° true. The wind component along the flight path is added to or subtracted from the airspeed as appropriate. The crosswind component results in a component along the flight path which is always subtracted. The head-wind component is given by:

$$HW = W \cos\theta + VC - (VC^2 - (W \sin\theta)^2)^{0.5}$$

where

HW is the headwind component (mph)

W is the windspeed (mph)

θ is the angle of the wind relative to the desired ground track, and

VC is the cruise speed of the aircraft (mph).

The Ground Speed (GS) for economics becomes:

$$GS = VC - HW.$$

Two standard deviations of wind-speed are subtracted from the groundspeed for economics to give the groundspeed for scheduling. Two standard deviations is 38 mph for all routes except Portland to Pendleton or Baker where it is 34 mph. The two standard deviations should be modified for route length, as shown in Figure 3-2. The resultant headwind components along the flight path, for both economics and scheduling, are adjusted to 60% of their cruise value during climb and descent as an approximation of their values at lower altitudes.

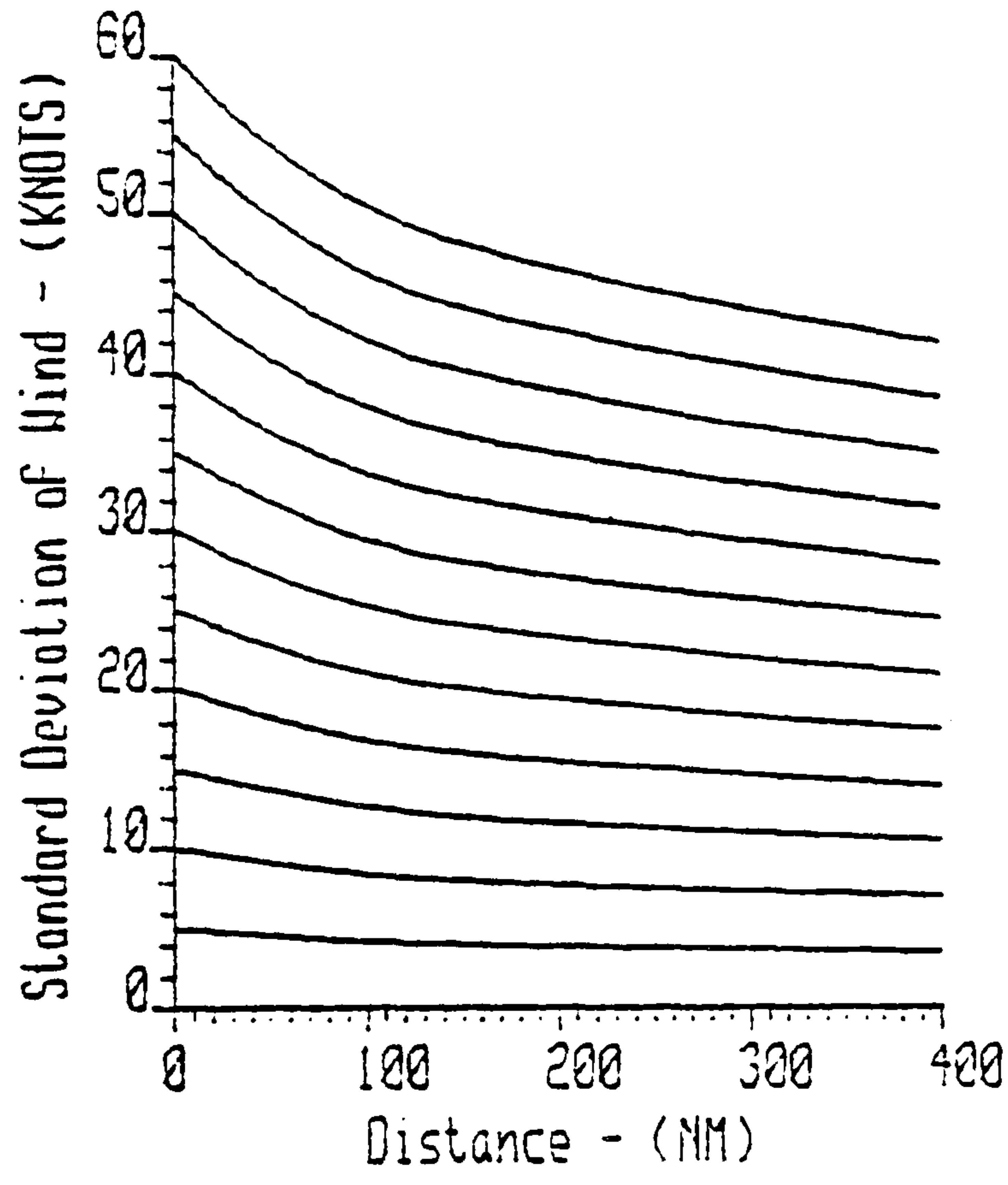


FIGURE 3-2
WIND STANDARD DEVIATION AS A FUNCTION OF TRIP DISTANCE

3.2.4.4 Ground and Air Manoeuvering Times

The ground manoeuver (GM) and air manoeuver (AM) times, in hours, are a function of Gross Take-Off Weight (GTOW), in pounds, according to Williams[49]:

$$GM = \frac{5.1\ GTOW}{10^7} + 0.125$$

and

$$AM = \frac{2.5\ GTOW}{10^7} + 0.0625.$$

3.2.4.5 Adjustments to Climb and Descent

The equations used for flight planning are linearizations of graphs in the aircraft flight manual. It was necessary to adjust the sea-level values of time to climb, distance to climb, fuel to climb, time to descend, distance to descend, and fuel to descend by a factor to account for the elevation of the departure and arrival airports. The equation had the form:

$$VU = SLV + \delta\ AE$$

where

VU is the value used,

SLV is the sea-level value,

δ is the change per foot of altitude, and

AE is the airport elevation (departure or arrival, as appropriate).

3.2.4.6 Block Time

Block time is the time from when an aircraft first moves under its own power for the purpose of flight until it comes to rest for the last time after flight prior to engine shutdown. Block times are a function of stage length, aircraft performance factors, ATC policies and procedures, and airport size and congestion (both airside and groundside).

Block time is found from:

$$BT = GM + AM + TC + TD + \left[\frac{D-DC-DD}{VC-HW}\right]$$

where

BT is the block time (hours),

GM is the ground manoeuver time (hours), Section 3.2.4.4,

AM is the air manoeuver time (hours), Section 3.2.4.4,

TC is the time to climb (hours) from the aircraft flight manual adjusted for departure airport elevation, Section 3.2.4.5, TD is the time to descend (hours) from the aircraft flight manual adjusted for arrival airport elevation, Section 3.2.4.5,

D is the stage length (sm)

VC is the cruise speed (mph) from the aircraft flight manual,

HW is the headwind component on the route (mph). If scheduling time is required, two wind standard deviations adjusted for route length are added, Section 3.2.4.3,

DC is the adjusted distance to climb (sm) found from:

$$DC = DC' - 0.6\ HW\ TC$$

where

DC' is the distance to climb from the aircraft flight manual adjusted for departure airport elevation, Section 3.2.4.5, and

HW and TC are defined above.

Similarly,

$$DD = DD' - 0.6\ HW\ TD$$

where

DD' is the distance to descend from the aircraft flight manual adjusted for arrival airport elevation, Section 3.2.4.5, and

HW and TD are defined above.

If the stage length is less than (DC + DD), then:

$$BT = GM + AM + (TC + TD)\left[\frac{D}{DC+DD}\right].$$

3.2.4.7 Block Fuel

Block fuel is the fuel used during block time. It is found from:

$$BF = 0.5(GM + AM)FF + FC + FD + \left[\frac{D-DC-DD}{VC-HW}\right] FF,$$

where

BF is block fuel in pounds,

FF is cruise fuel flow in pounds per hour, FC is the fuel to climb from the aircraft flight manual adjusted for the departure airport elevation, Section 3.2.4.5,

FD is the fuel to descend from the aircraft flight manual adjusted for the arrival airport elevation, Section 3.2.4.5, and

GM, AM, D, DC, DD, VC and HW are defined in Sections 3.2.4.3, 3.2.4.4 and 3.2.4.5.

If the stage length is less than (DC+DD), then:

$$BF = 0.5(GM + AM)FF + (FC + FD)\left[\frac{D}{DC+DD}\right].$$

3.2.4.8 Aircraft Utilization

Aircraft utilization, in hours per year, is directly affected by many factors. It is normally computed from a formula based on the average block time, but a large variation in block times may also affect utilization.

The time required in the blocks, turnaround time, is also important in determining utilization (its importance is inversely related to block time). Its value is a function of aircraft size, aircraft service time, ATC policies and procedures, and block time.

How demand is distributed throughout the day, week, and year are also determinants of utilization. The general level of demand may be a function of frequency, i.e., utilization, which may be a function of economics or airline policy. (Is the airline promoting or demoting the route, or simply maintaining a status quo?) Aircraft maintenance requirements partially determine utilization and are a function of aircraft size, ease of service, MTBF, MTBMA, aircraft availability, and the maintenance system (Appendix G). Politics are important. What cities must be served? How often? During what times of the day? Are there curfews or arrival/departure windows?

The airline must also consider two other factors in planning aircraft utilization. First, the airline needs to be reliable. Therefore, it can't schedule what it can't perform on a regular basis. Second, actual planning is more difficult than using formulae; formulae give continuous numerical answers, but block times, turnaround times, maintenance times, passengers, departures, arrival/departure windows, etc., occur in discrete, discontinuous blocks.

An attempt was made to correlate the surveyed airlines' average annual utilization with various aircraft and route system parameters. While there was a general increase in utilization with block time, the regression lacked statistical significance. Therefore, another approach was taken. Faulkener[52] developed a daily utilization formula for local service carriers based on block time:

$$U = \frac{13.1}{1 + (0.572/BT)}$$

where

U is the daily utilization (hours), and

BT is the average block time (hours).

The corresponding annual utilization (U_1) is found from:

$$U_1 = \frac{4781}{1 + (0.572/BT)}$$

The numerator used for the third-level airline is based on the survey of third-level airlines and has a value of 4120 for aircraft comparison. The numerator used for costing on the proposed routes in 1978 is 4382 and in 1987 is 4506 because aircraft are purchased in whole units. The increase in the numerator, +3%, between 1978 and 1987 is justified by the reductions in inspections, service bulletins, airworthiness directives (ADs) and the mechanics' familiarity with the aircraft, Section 3.2.1.2.

3.2.4.9 Aircraft Payload

The payload is the GTOW, adjusted for altitude and temperature, minus the Basic Operating Weight (BOW), block fuel, and reserve fuel. The BOW is the aircraft manufactured weight plus airframe options, avionics, undrainable fuel, normal oil level, normal stores, and crew.

3.2.4.10 Changes in Flight Planning with Time

The aircraft are assumed to gain weight at the rate of 0.21% (17 lbs) per year to account for paint, repairs, modifications, and accumulated dirt resulting in a corresponding decrease in payload. Engines generally lose 2-3% of their specific fuel consumption (sfc) during the first 1000-2000 hours of operation and then they level off. Airframes, too, generally "relax" from their new shape and acquire "hangar rash" throughout their life. This results in performance reductions of an additional 2-3%. The combined effects of sfc increase, airframe relaxation, and hangar rash are assumed to result in a reduction in speed throughout the flight regime of 0.4% per year, or 4% over the life of the aircraft.

3.2.5 Aircraft Operating Costs

Aircraft operating costs were investigated in terms of airline production parameters, operating constraints, and time. The method of investigation was, again, regression analysis as it had proved successful in the past. Four airlines supplied operating cost data for the regression; one supplied four years of data, two supplied three years of data, and one supplied one year of data. The time span was years 1972 to 1976, inclusive. All the airlines except one were private corporations and limited access to their financial data; seventy-five percent of the airlines contacted would not release financial data.

The following cost determinants were sought by regression:

1. Number of pilots
2. Pilot salaries
3. Number of mechanics
4. Mechanic salaries
5. Maintenance burden
6. Airframe material
7. Engine costs

Attempts were made to explain the above in terms of the following independent variables or appropriate combinations:

1. Revenue-passenger-miles (RPM) per year
2. Aircraft departures per year
3. Number of pilots
4. Number of mechanics
5. Block hours per year
6. Number of aircraft operated
7. Airframe empty weight
8. Aircraft type
9. Seats per aircraft
10. Revenue miles flown per year
11. Year of operation (1972, 1973, 1974, 1975, 1976)

Air freight is not considered as an independent variable because this averages only 3-15% of total revenue for third-level airlines carrying both passengers and freight. Each 191 lbs of air freight is treated as the equivalent of one passenger for both passengers boarded and RPM calculations (Sections 5.3.1 and 5.3.3.2).

3.2.5.1 Aircraft Cost Per Block Hour

The hourly aircraft cost was simply the annual aircraft cost (Table 3-4) divided by the computed utilization (hours) on the route being analyzed, Section 3.2.4.6. To get the cost per mile, the cost per hour was factored by (block time (hours)/distance (sm)).

3.2.5.2 Fuel and Oil

Fuel cost is composed of the fuel for ground manoeuvering, air manoeuvering, climb, cruise and descent as adjusted for airport altitudes and wind. Fuel weight is similarly composed plus, for VFR flight, a 30-minute reserve (62% of the time), or, for IFR flight, fuel to reach a 100 nm alternate plus a 45-minute reserve (38% of the time).

The Federal Energy Administration (FEA) guidelines state that the Fixed-Base Operator (FBO) services the needs of all carriers except CAB certificated carriers. Therefore, even though third-levels purchase more than 84000 gallons per year at many stations, legally qualifying them for wholesale fuel prices, wholesale prices are discretionary with the FBO. The FBO often has a monopoly at the airport so third-level airlines are sometimes charged prices twice as high as certificated carriers. Third-level carriers feel the FEA should change their policy to include all scheduled carriers.

At airports where several third-level carriers operate and there is more than one FBO, they are beginning to pool their fuel dealings to get leverage. They would like to pay wholesale prices plus an enplanement fee (cents/gallon).

Wholesale fuel prices should run from 33 to 39 cents per gallon in 1978. Enplanement fees run from 2.5-10 cents per gallon and average about 6 cents per gallon. Occasionally the airport authority charges an additional 0.5-3 cents per gallon flowage. States may also tax fuel not used in certificated operations. This results in wholesale prices of 36 to 52 cents per gallon before state taxes and in retail prices of 48 to 63 cents per gallon from FBOs.

Oil companies were contacted to find out the fuel price offered by their dealers based on the wholesale price plus an enplanement fee. Prices ranged from 42.3 to 44.6 cents per gallon. The state of Oregon adds a 7 cent per gallon tax and the city of Medford charges 3 cents per gallon flowage. The average of the fuel prices used in the analysis was 52 cents per gallon.

Fuel increases were generated as subjective probability distributions, discussed in Appendix B, by an economist for a major oil company. Other oil companies were contacted, but were unable to respond in probabalistic terms. Crude oil was forecast to increase 3.5% per year or 41% in real terms over the ten-year period. This was equivalent to a 1.84% per year, or 20% over the period, rise in Jet-A price at the pump. The mean projected cost in 1987 was 62.4 cents per gallon.

Oil prices are less important. The Metro uses 0.009 gallons per hour per engine. The price for the synthetic oil is \$13.00 per gallon in 1978 and, based on the fuel projection, will be \$15.60 per gallon in 1987 (1978 dollars). Both fuel and oil are factored by the cost program by 1.03 to allow for training.

3.2.5.3. Number of Pilots

The number of pilots required was best calculated from the number of departures per year:

$$NP = K1 + K2\ D$$

where

NP is the number of pilots,

K1 (4.36035) is the calibration constant,

K2 (1.28876) is the coefficient of D, and

D is the number of departures (000s) per year.

Table 3-8 gives the equation statistics. However, if block times are too long the pilot could exceed the maximum flight time allowable per year (1000 hours). In order to compensate for this possibility, pilots are limited to 960-hours per year scheduled duty time. The 40 hours of unassigned time could be used for standby, additional training, the inevitable vagaries of crew scheduling, and actual versus planned flight times.

In this study, two extra pilots are required for the Metro II in 1978 because of the 960 hours-per-year time limit, 55 pilots, and two more pilots are required in 1987, 57 pilots, because of aircraft performance degradation. Of the 55 pilots in 1978, 28 should be captains, 3 reserve captains, and 24 copilots. In 1987, the captain and copilot ranks each increase by one. A reserve captain is a crew member normally scheduled and paid as a copilot that is qualified to serve as captain and is paid as a captain when he acts in that capacity. This position would be held by the three most senior copilots.

3.2.5.4 Pilot Salaries

If an airline has long, dense routes requiring large aircraft its productivity (revenue) per employee will, ceteris paribus, be higher than if it has short, sparse routes; it can, therefore, pay employees more. While revenue per employee is not the only criterion for compensation, it does affect funds available. Because of this economic reality, third-level airline employees have found certificated carrier wage levels impossible to achieve.

Pilot salaries are best determined by:

$$PS = K1 + K2\ (RPM/NP)$$

where

PS is the average pilot's annual salary in thousands of dollars,

TABLE 3-8

NUMBER OF PILOTS MODEL

```
LINEAR REGRESSION OF NUMBER OF PILOTS AGAINST NUMBER OF DEPARTURES (000'S)

CORRELATION COEFFICIENTS

  1.000  0.977
  0.977  1.000
ORIGINAL VALUES
 MULTIPLE REGRESSION   N=  11   M=   2
 VARIABLE   MEAN       ST.DEV.      CORREL.      REG.CO.    S.E. OF R.C. COMP. T
    2    28.43013    11.28267     0.97680      1.28876      0.09418     13.68426
 DEPENDENT
    1    41.00000    14.38624
 INTERCEPT  4.36035   MULTIPLE CORRELN.  0.97680   S.E. OF ESTIMATE  3.36024
 ANALYSIS OF VARIATION          DF         SUM SQ      MEAN SQS.       F VALUE
ATTRIB. TO REGRESSION            1     2114.37912    2114.37912     187.25888
DEVIATION FROM REGRESSION        9      101.62088      11.29121
CORR. MULT. CORRELN.    0.97680
AUTO-CORRELN. OF RES. -0.34031
VON NEUMANN RATIO       2.72420
HETEROSCEDASTIC CORRELN.  0.28442
HETEROSCEDASTIC T-COMP.   0.89001
  NO.      OBS.Y        EST.Y      RESIDUAL
   1     33.00000     39.08854    -1.08854
   2     70.00000     67.91807     2.08193
   3     57.00000     54.50725     2.49275
   4     48.00000     54.79077    -5.79077
   5     24.00000     27.35310    -3.35310
   6     26.00000     25.68156     0.31842
   7     28.00000     24.48819     3.51181
   8     24.00000     24.31292    -0.31292
   9     41.00000     41.99469    -0.99469
  10     46.00000     46.21924    -0.21924
  11     49.00000     44.64566     4.35434
```

K1 (7.89051) is the intercept or annual base wage in thousands of 1976 dollars, $7890.51,

K2 (0.00954) is the coefficient of RPM (000's) per pilot in thousands of dollars or 0.954 cents per RPM,

RPM is thousands of revenue-passenger-miles per year (including air freight at 191 pound-miles per passenger-mile), and

NP is the number of pilots.

Table 3-9 gives the complete statistics. In 1978 dollars, these amounts became 9085 dollars per year and 1.098 cents per RPM per pilot in 1978 and 10804 dollars per year and 1.306 cents per RPM per pilot in 1987. These average numbers were then factored by 1.13 for captains and 0.80 for copilots because copilots usually make 65-70% of a captain's wage.

This equation shows the effects of productivity on the industry pay schedule, not the method by which the industry pays. The industry either pays by the block hour or pays a fixed salary per month for block time up to a specified amount after which overtime is paid. In the set-up of the hypothetical airline, it is proposed to use this formula (and it, or a similar one, is recommended). This offers the advantage of increased employee responsibility for production, better wages with better production, and reduced cash outflows when production is low.

3.2.5.6 Flight Attendant Salaries

A flight attendant must be provided on the Mohawk 298 because the aircraft has more than 19 passenger seats (FAR part 135.2). Flight attendants, when required, have more personal contact with the passengers than any other airline employee. It is, therefore, most important that they project the proper image and personality. Because of this, they are paid more ($7.50 per hour) than the minimum wage ($2.85 per hour) and given the same duty time limitations as the flight deck crew.

3.2.5.7 Number of Mechanics

Without a doubt, the inability to describe the number of mechanics required from the data available was the biggest disappointment in the costing. The number of mechanics required could not be shown to be a function of any of the airline's statistics, e.g., hours flown, number of aircraft, number of departures, aircraft type. Therefore, discussions with airline personnel, aircraft manufacturers, and a study by Pay[53] were relied upon.

It was agreed among those with whom discussions were held, that aircraft of the nineteen-seat category all had a man-hour per block-hour rate of 1.9-2.0 at introduction of the aircraft and that this dropped to 1.4-1.5 within 1-2 years after the first aircraft was operational. But Air Midwest, by making large Metro II orders (≥ 4), had received free factory representatives on site for six months

TABLE 3-9

PILOT SALARIES MODEL

```
LINEAR REGRESSION OF MEAN PILOT'S SALARY (000'S) IN 1976 DOLLARS
AGAINST MEAN REVENUE PASSENGER MILES (000'S) PER PILOT

CORRELATION COEFFICIENTS

  1.000  0.818
  0.818  1.000
ORIGINAL VALUES
 MULTIPLE REGRESSION    N=  11    M=   2
 VARIABLE   MEAN        ST.DEV.       CORREL.       REG.CO.    S.E. OF R.C. COMP. T
    2   507.99555   194.23171       0.81778       0.00954      0.00224      4.26270
 DEPENDENT
    1     12.73573      2.26536
 INTERCEPT  7.89051   MULTIPLE CORRELN.  0.81778   S.E. OF ESTIMATE  1.37432
 ANALYSIS OF VARIATION          DF          SUM SQ      MEAN SQS.        F VALUE
ATTRIB. TO REGRESSION            1        34.31995      34.31995        18.17064
DEVIATION FROM REGRESSION        9        16.99883       1.88876
CORR. MULT. CORRELN.     0.81778
AUTO-CORRELN. OF RES. -0.37042
VON NEUMANN RATIO        2.31793
HETEROSCEDASTIC CORRELN.  0.57525
HETEROSCEDASTIC T-COMP.   2.10977
  NO.       OBS.Y        EST.Y       RESIDUAL
   1      11.25900     13.99022     -2.73122
   2      10.52200     10.46093      0.06107
   3      11.00400     10.45699      0.54701
   4      11.06500     10.38687      0.67813
   5      11.95500     13.07227     -1.11727
   6      11.29400     12.89439     -1.60039
   7      11.75200     11.96663     -0.21463
   8      13.52500     12.57592      0.94908
   9      17.47000     16.19395      1.28205
  10      15.52300     14.64151      0.88149
  11      14.71800     13.45332      1.26468
```

for both the airframes and the engines eliminating unnecessary removals and maintenance. As large orders were to be placed, a learning curve was not included in the analysis.

Pay's formula is the following:

$$M = 2\ (WE/10^4)$$

where

M is the man-hours per block-hour, and

WE is the empty weight of the aircraft minus the weight of the engines, i.e., the airframe empty weight.

This gave a value for the Metro of 1.422 (man-hours per block-hour) in 1978. Assuming mechanics work 1920 hours per year and that the airline, operating Metros, flies 26589 hours per year in 1978 in scheduled service, training, ferrying, and weather diversions, then 20 mechanics will be required. In 1987, 21 mechanics will be required because of increased flight times and weight growth. The increase in costs from an increased number of mechanics is allowed, but the engineering learning curve is assumed to compensate for real salary growth (2.0% per year). This requires that, in reality, the actual number of mechanics decrease.

3.2.5.7 Mechanic Salaries

Mechanic salaries are calculated similar to pilot salaries:

$$MS = K1 + K2\ (RPM/NM)$$

where

MS is the average mechanic's annual salary in thousands of dollars,

K1 (9.93102) is the intercept or annual base wage in thousands of 1976 dollars, $9931.02,

K2 (0.00253) is the coefficient of RPM (000's) per mechanic in thousands of dollars or 0.253 cents per RPM,

RPM is thousands of revenue-passenger-miles per year (including air freight at 191 pound-miles per passenger-mile), and

NM is the number of mechancis.

Complete statistics are given in Table 3-10. Salaries are a weak function of RPMs per mechanic, reflecting that wages are a function of the airline's ability to pay. For years 1978 through 1987 the salary is expressed in terms of 1978 dollars, the base salary is 11007 dollars per year and the productivity component is 0.28 cents per RPM per mechanic.

TABLE 3-10

MECHANIC SALARIES MODEL

```
LINEAR REGRESSION OF MEAN MECHANIC'S SALARY (000'S) IN 1976 DOLLARS
AGAINST MEAN REVENUE PASSENGER MILES (000'S) PER MECHANIC

CORRELATION COEFFICIENTS

  1.000  0.751
  0.751  1.000
ORIGINAL VALUES
 MULTIPLE REGRESSION    N=  11    M=   2
 VARIABLE    MEAN        ST.DEV.       CORREL.       REG.CO.    S.E. OF R.C.  COMP. T
    2  1725.84664   759.77094      0.75150       0.00253      0.00074      3.41727
 DEPENDENT
    1     14.29745      2.55788
 INTERCEPT  9.93102   MULTIPLE CORRELN.  0.75150    S.E. OF ESTIMATE  1.77881
 ANALYSIS OF VARIATION          DF          SUM SQ      MEAN SQS.       F VALUE
ATTRIB. TO REGRESSION           1        36.94998      36.94998      11.67770
DEVIATION FROM REGRESSION       9        28.47733       3.16415
CORR. MULT. CORRELN.    0.75150
AUTO-CORRELN. OF RES. -0.02769
VON NEUMANN RATIO       2.0687
HETEROSCEDASTIC CORRELN. -0.54145
HETEROSCEDASTIC T-COMP.   -1.93207
  NO.       OBS.Y        EST.Y       RESIDUAL
   1     14.30300     15.52051     -1.21751
   2     11.58300     13.90836     -2.32536
   3     11.62000     12.91600     -1.29600
   4     10.30300     12.82055     -2.51755
   5     14.60600     13.22985      1.37615
   6     13.99100     13.06834      0.92266
   7     13.59500     12.45390      1.14110
   8     15.44300     12.64270      2.80030
   9     15.80700     15.95137     -0.14437
  10     16.76800     16.79564     -0.02764
  11     19.25300     17.96478      1.28822
```

An additional \$0.993 (1978) or \$0.963 (1987) per block hour representing avionics labor, based on a Rate-Per-Hour Contract (Section 4.5.2), is added to the labor costs of this section.

3.2.5.8 Engine Reserves

Engine reserves for the Garrett TPE - 331-303G are based on quoted prices for the overhaul and hot-section inspection kits. The overhaul kits list for \$33000 and the current mean-time-between-overhaul (MTBO) is 4000 hours. The cost for the overhaul kit is \$8.25 per hour per engine. The hot-section kits cost \$5500 and the mean-time-between-hot-section inspections is 2000 hours. The cost for the hot-section kit is \$2.75 per hour per engine. The parts are assumed to constitute 80% of the cost of overhauls so the hourly parts cost of \$11 is increased by \$2.75 (25%) to allow for labor. This gave a figure of \$13.75 an hour per engine which is the figure suggested by Garrett AiResearch, the manufacturer, and Cooper Airmotive, an overhaul facility.

Engine costs are held constant with time. Operators complained about the rising cost of engine overhauls. Increases as high as 26% per year over the years 1973-1976 were cited for the turbine of a Pratt & Whitney PT6A. One airframe manufacturer said that engine overhauls had increased 11-25% per year in real terms, depending on the overhaul agency, for the years 1974-1975. However, engine manufacturers could demonstrate that increases in the Time-Between-Overhaul (TBO) virtually matched the increased costs.

With 80% of the overhaul consisting of parts, decreasing by 2% over the period, and 20% of the overhaul consisting of labor, increasing 21.4% over the period, the projected real change over ten years is +2.7%. Engine manufacturers anticipate continued gains in TBO's equaling or exceeding any real-cost increases, thus justifying the approach of holding engine cost per unit-of-productivity constant with time.

3.2.5.9 Airframe Material

This is traditionally the toughest quantity to predict accurately. Further, because of airline equipment differences, it is necessary to rely on airline accounts rather than regression techniques.

The formula developed was the following:

$$AC = 2.42\ (WE/10^3)$$

where

AC is the airframe cost in 1978 dollars per hour, and

WE is the empty weight of the aircraft minus the weight of the engines (airframe empty weight).

It gives a value for the Metro of \$17.20 per hour in 1978 and \$17.26 per hour in 1987 when WPIIC, weight growth, and training costs are included.

An additional \$0.348 per block hour representing avionics material, based on a Rate-Per-Hour Contract (Section 4.5.2), is added onto material cost since it is not included in airframe material cost.

3.2.5.10 Maintenance Burden

Because the accounts of only two third-level airlines had maintenance burden as a separate item, examination rather than regression analysis was used to determine maintenance burden. It was found to be best represented by 78% of airframe labor costs.

Maintenance burden for commuters is less than certificated carriers because of the reduced record keeping requirements of FAR part 135 and the "two eyes" system of inspection rather than designated inspectors.

3.2.5.11 Insurance

The cost of hull and liability insurance is generally taken as a composite amounting to 1.8% of the hull value for a new operation and decreasing at the rate of approximately 0.1% per year to the industry average of 1.5% per year in the fourth year. This costing scheme was followed. Operators with high loss-ratios may pay over 2% per year while well-established operators with very low loss ratios may only pay 1.2% per year. In general terms, about 60% is hull and 40% liability; hull is a slightly greater percentage (≅65%) in the early years and liability is often a function of revenue-passenger-miles or available-seat-miles.[54]

3.2.5.12 Pilot and Mechanic Training

The manufacturer will provide all initial training of pilots and mechanics. Training time for pilots and mechanics is two weeks. It is proposed that in their second year pilots receiving recurrent training be sent to Flight Safety, Inc. for complete ground and simulator training ($3000/pilot/year). After a pilot's second year, all training should be done in-house. Dedicated flight time for training will be approximately 15 hours per pilot per year. After the first year, lead mechanics and the manufacturers representatives (airframe and engine) will address specific maintenance problem areas.

3.2.5.13 Unionization

Most third-level operators are openly afraid of the effects of unionization. They see the rules and rates of the local service and trunk industries and realize that they could not survive under such a cost structure. Those who have been forced to unionize have discovered that, generally, their fears are unfounded. The unions realize the financial position of many commuters and have made their demands within that framework.[4]

Of the eleven years of airline accounts and four airlines, five and one-half years and two airlines were union (one airline was unionized in the middle of an accounting year). The two nonunionized airlines had employees that had voted in a union, but were working without a contract. In this study, unionization was treated as a dummy variable. The variable was never found to be statistically significant. However, on a purely arithmetic basis, unionized airlines were found to employ 1.57 (3.9%) more pilots and to pay those pilots $1590 (13.3%) more per year. Mechanics, on the other hand, were paid an average of $2115 (16.0%) more per year in nonunionized airlines.

Airline management's biggest worry was decreased productivity. The accounts of the airline that was unionized during the period confirmed this. Before unionization it was 6.79 (-12.4%) pilots short as estimated by the regression formula. After unionization it was 2.08 (3.1%) pilots over the estimate for the first year and 2.49 (4.5%) pilots over the estimate for the second year. Salaries were essentially unchanged. (They actually decreased very slightly in real terms.)

The airline management that most vehemently opposed unions paid their pilots slightly less than predicted, but had, as an average, the predicted number of pilots. (The most recent pilot number was down relative to predictions, possibly because of union organizing activities.) On the other hand, the airline had so many mechanics relative to aircraft and hours flown that it ruined the regression for predicting the number of mechanics. It also paid its mechanics $1500 per year more than any of the other airlines.

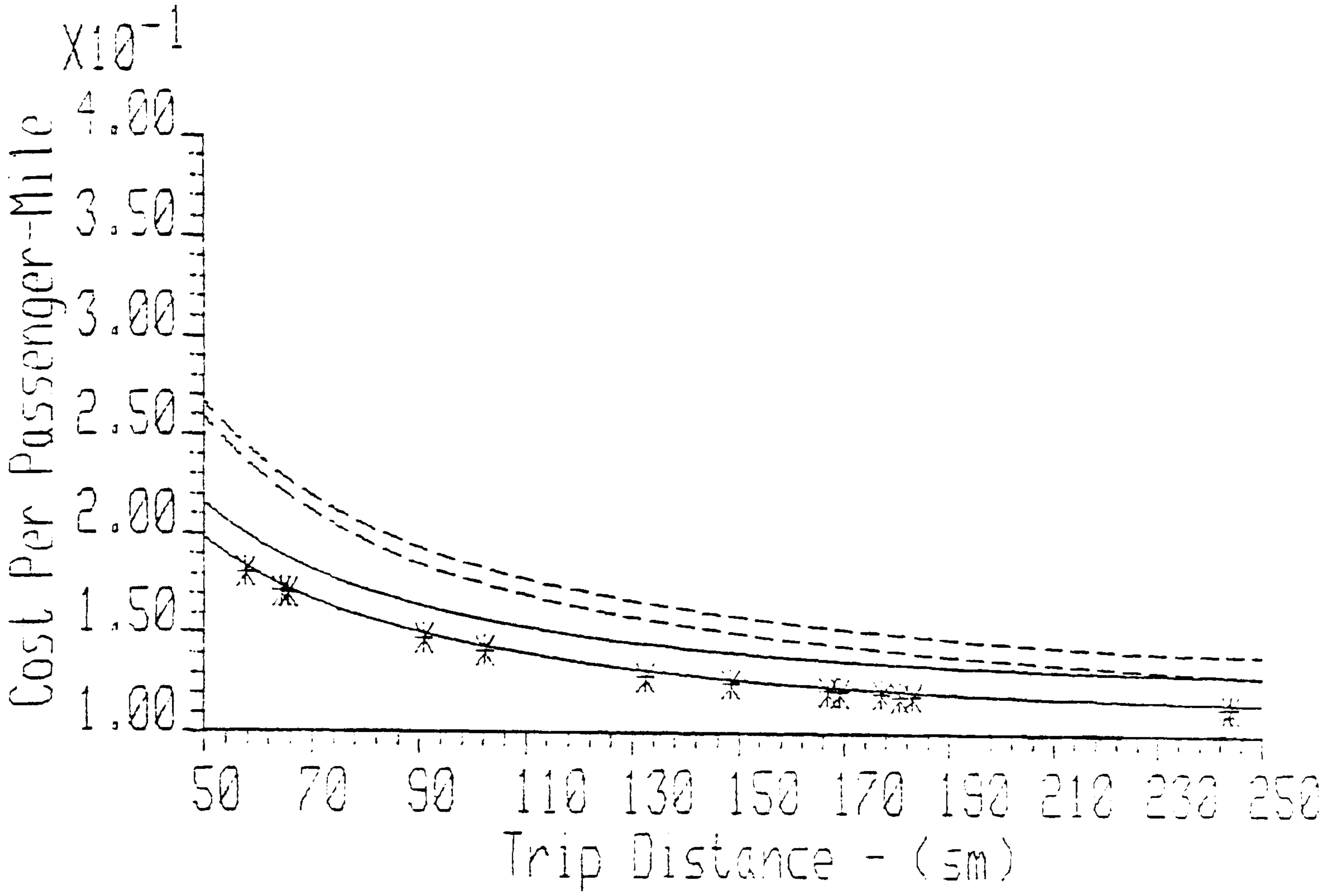
In summary, unionization, while statistically insignificant, may tend to bring an airline in-line with the rest of the industry.

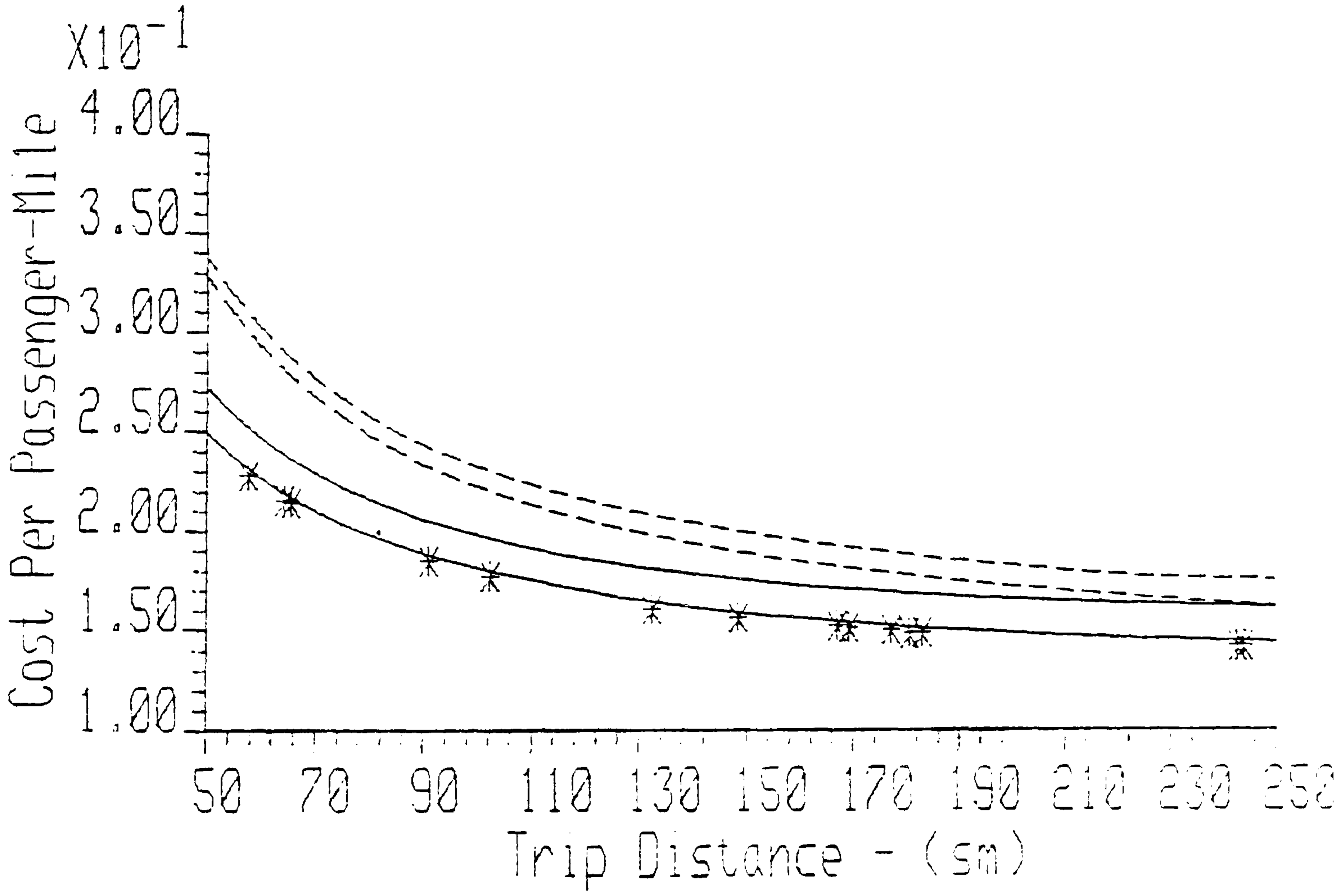
3.2.6 Direct Operating Cost Graphs

Graphs were prepared on the basis of the preceding formulae and computed costs to compare the Swearingen Metro II and the Mohawk 298. The solid lines represent the Metro and the dashed lines the Mohawk 298. A pair of solid and dashed lines appear on each graph representing 1978 and 1987. The difference between 1978 and 1987 being aircraft speed (-2%), aircraft weight (+2%), fuel consumption (+2%), fuel and oil cost (+20%), crew cost (+21.4%), and parts cost (-2%). Costs are in 1978 dollars.

The asterisks (*) represent the actual operation of Metros from Oregon stations, as determined in Section 5, in 1978 at presumed load factors of 45% or 35%. They take into account field elevation, wind direction, meteorological completion factors, and an integer number of aircraft.

The first graph (Figure 3-3) shows cost per passenger-mile versus trip distance at 45% load factor (upper graph) and 35% load factor (lower graph) for both aircraft. Load factors were based on available seats (payload (lbs)/(191 lbs/passenger)) as opposed to installed seats. The graphs encompass the airline's most-likely load factors for 1978 through 1987. These graphs, in conjunction with the route selection and pricing program, Section 5, were used to select the Swearingen Metro II rather than the Mohawk 298. The route selection and pricing program showed that load factors for the aircraft in 1978 and 1987 were within 2% of each other after optimization. The Mohawk 298 had more seats per departure (connecting travel demand equation), but the Metro II offered greater frequency because of shorter block and turnaround times and more time savings because of higher speed (intra-Oregon travel demand, connecting travel demand, and air freight demand equations). The aircraft





LEGEND

Upper Graph - 45% Load Factor	Swearingen Metro ————
Lower Graph - 35% Load Factor	Mohawk 298 -------
Oregon Routes with Metro - 1978 *	Lower Line - 1978

FIGURE 3-3
COST PER PASSENGER-MILE VERSUS TRIP DISTANCE

became more competitive at longer ranges because the Metro II was operating on the exchange portion of the range-payload curve and its available seats were decreasing. These graphs show the increases in cost per unit of productivity (RPM) typical of shorter stages. When costs are added to the difficulty the air mode has in yielding a time savings over short stages, it is easy to see why the short stage-length markets are the most difficult to make profitable.

Figure 3-4 shows the cost per trip versus trip distance at 45% and 35% load factors. The reason the upper graph (45% load factor) is very slightly more than the lower graph is because the pilots and mechanics are paid partially on the basis of RPMs.

Figure 3-5 shows the annual aircraft cost versus trip distance. It is simply the cost per trip multiplied by the number of trips as determined from the utilization equation and block time (U_1/BT).

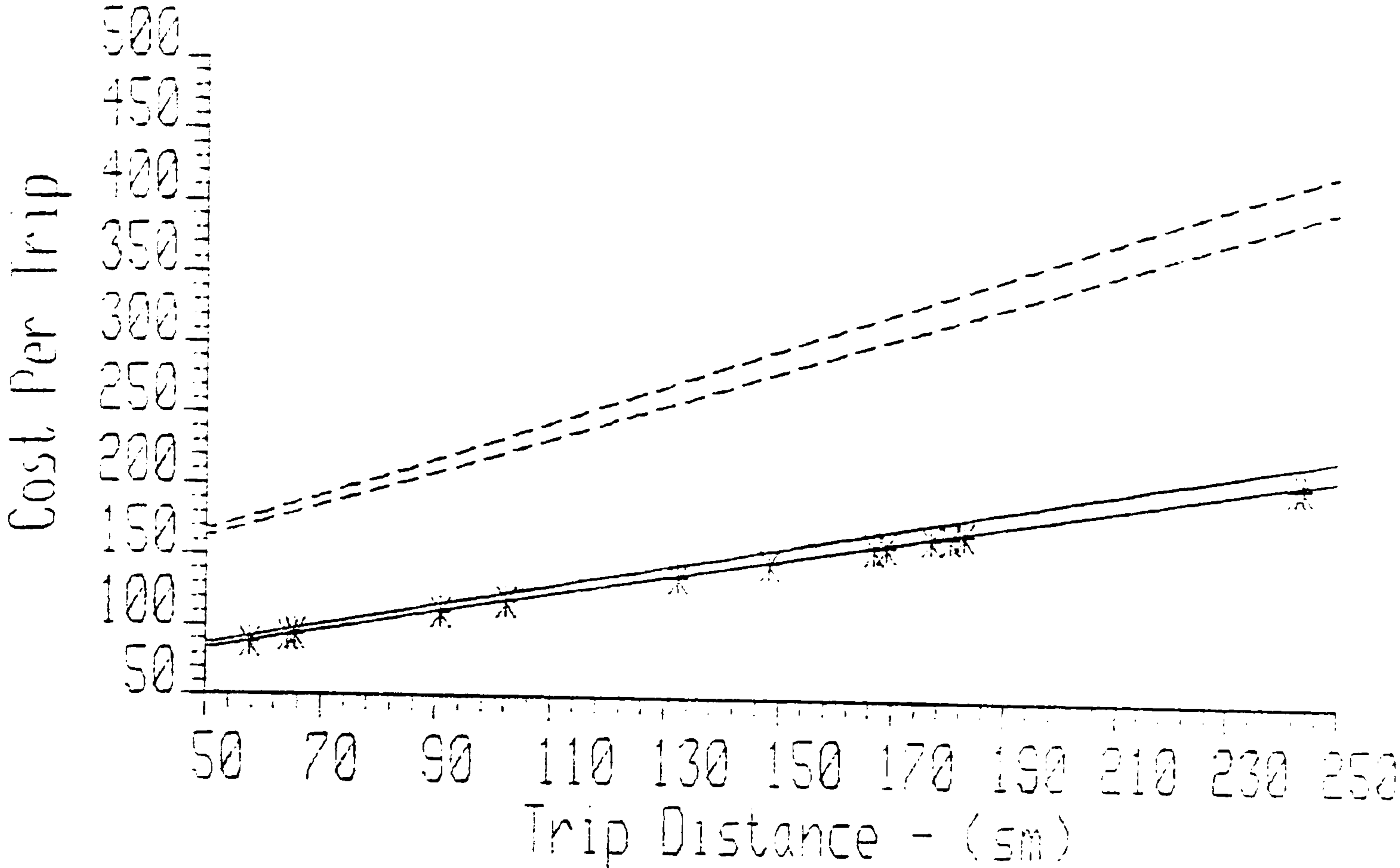
A topic of current interest is fuel efficiency. Figure 3-6 shows the pounds of fuel per passenger-mile versus trip distance. The discontinuity in the Metro II graph at 113.3 statute miles occurs because on shorter trips this aircraft is presumed to be either climbing or descending, never cruising. This is a pessimistic assumption, but its effects on cost are negligible.

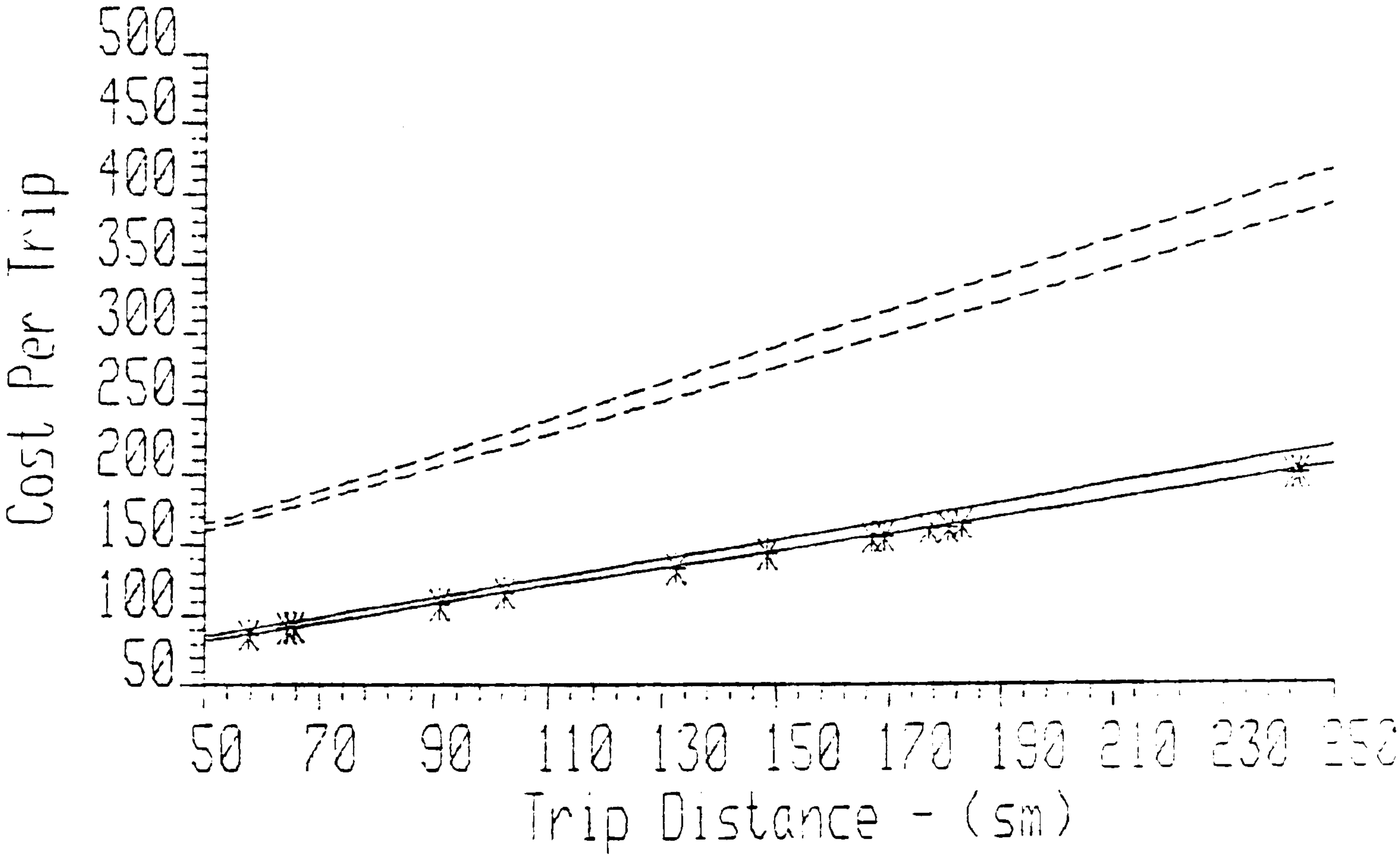
Figure 3-7 has two different graphs, neither of which are not a function of load factor. The top graph plots available-passenger-seats versus trip distance. In effect, this is a range-payload curve over a selected range with payload in terms of available seats. The Mohawk 298 has all 28 seats available until the later years at the longer distances when only 27 seats will be available. The Metro, on the proposed routes, never has 19 seats available. This is somewhat misleading because children under 12 years of age are computed at 71.3% of adult weight and, hence, the seats in some instances could be used. Second, adult passengers were computed on the basis of 191 pounds per person including baggage, Section 5.3.1. This conservatism is necessary because of the smaller serviceable demand per flight; relatively few passengers mean that load-to-load gross passenger weights may vary more than with greater demand (Section 5.3.2.1).

Productivity (available-ton-miles per hour (ATM/Hour)) is given in the lower graph. It is the payload multiplied by the block speed. Block speed is a function of route length. The lessor slope of the Metro II graph results from the Metro II being on the exchange portion of the range-payload curve.

3.2.7 Direct Operating Cost Summary

Based on the results of this section and the schedule determined in Section 5.2 the percentage breakdown of direct operating costs is given in Table 3-11 for 1978 and 1987. The mean cost per block hour is \$206.40 in 1978 and \$221.72 in 1987 (1978 dollars). In "The Air Midwest Service Determination" the cost of operating the Metro was estimated to be \$190.39 per block hour in June 1976.[5] In 1978 dollars this amounts to \$204.50, a -0.9% difference which may be accounted for by nearly any one of the factors composing cost.





LEGEND

Upper Graph - 45% Load Factor
Lower Graph - 35% Load Factor
Oregon Routes with Metro - 1978 *

Swearingen Metro ————
Mohawk 298 - - - - - - -
Lower Line - 1978

FIGURE 3-4
COST PER TRIP VERSUS TRIP DISTANCE

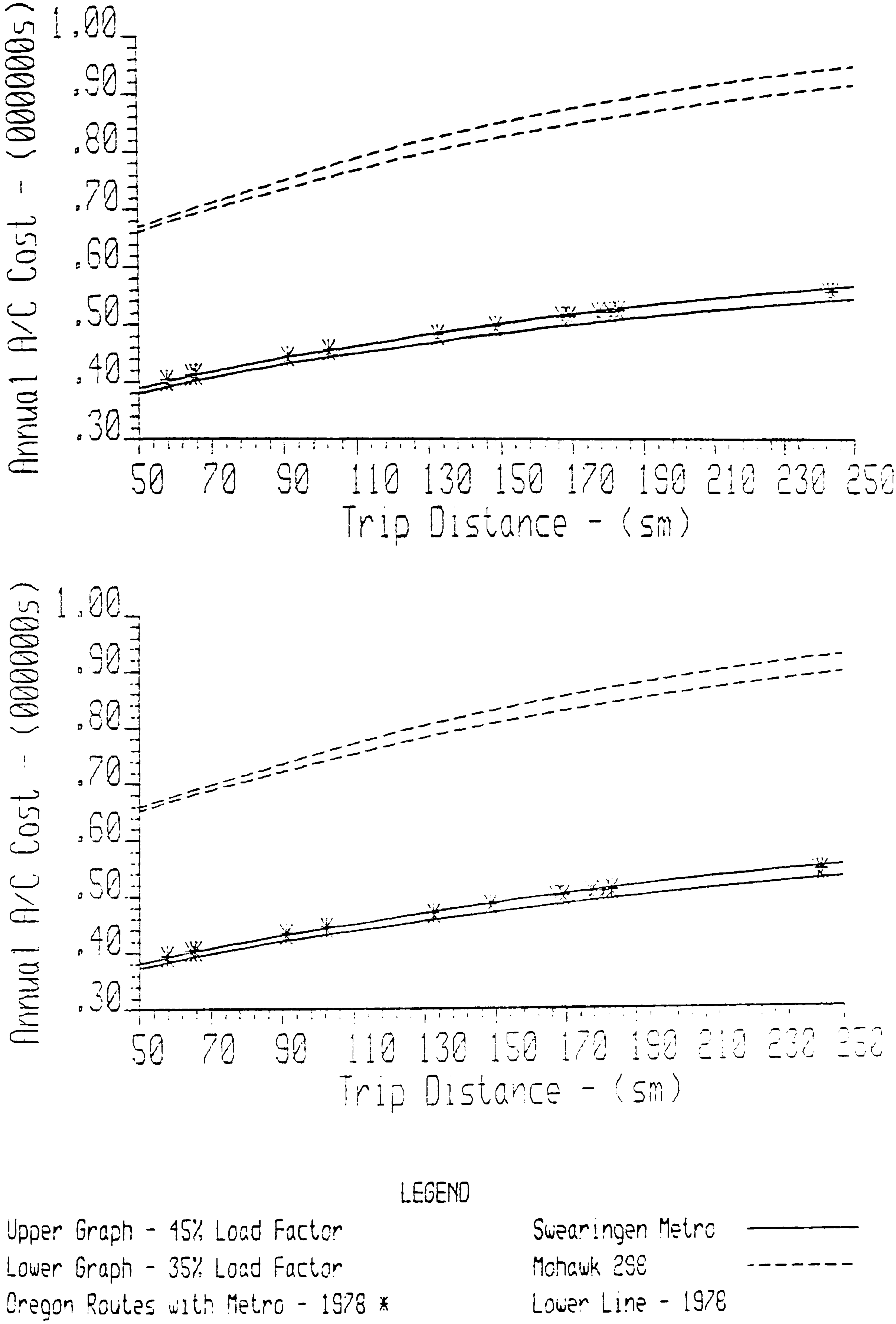
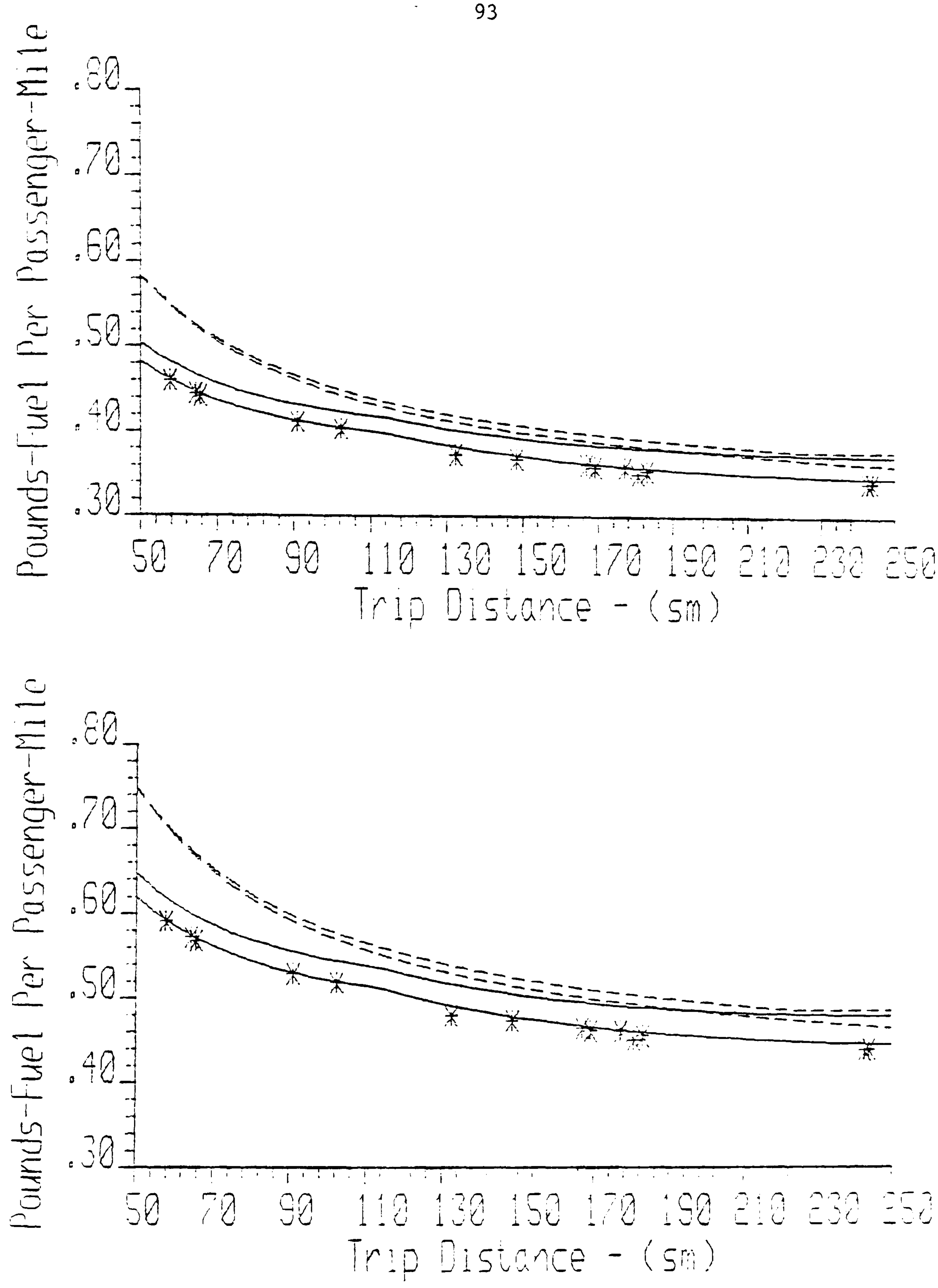


FIGURE 3-5
ANNUAL AIRCRAFT COST VERSUS TRIP DISTANCE



LEGEND

Upper Graph - 45% Load Factor	Swearingen Metro ————
Lower Graph - 35% Load Factor	Mohawk 298 - - - - - -
Oregon Routes with Metro - 1978 *	Lower Line - 1978

FIGURE 3-6
POUNDS-FUEL PER PASSENGER-MILE VERSUS TRIP DISTANCE

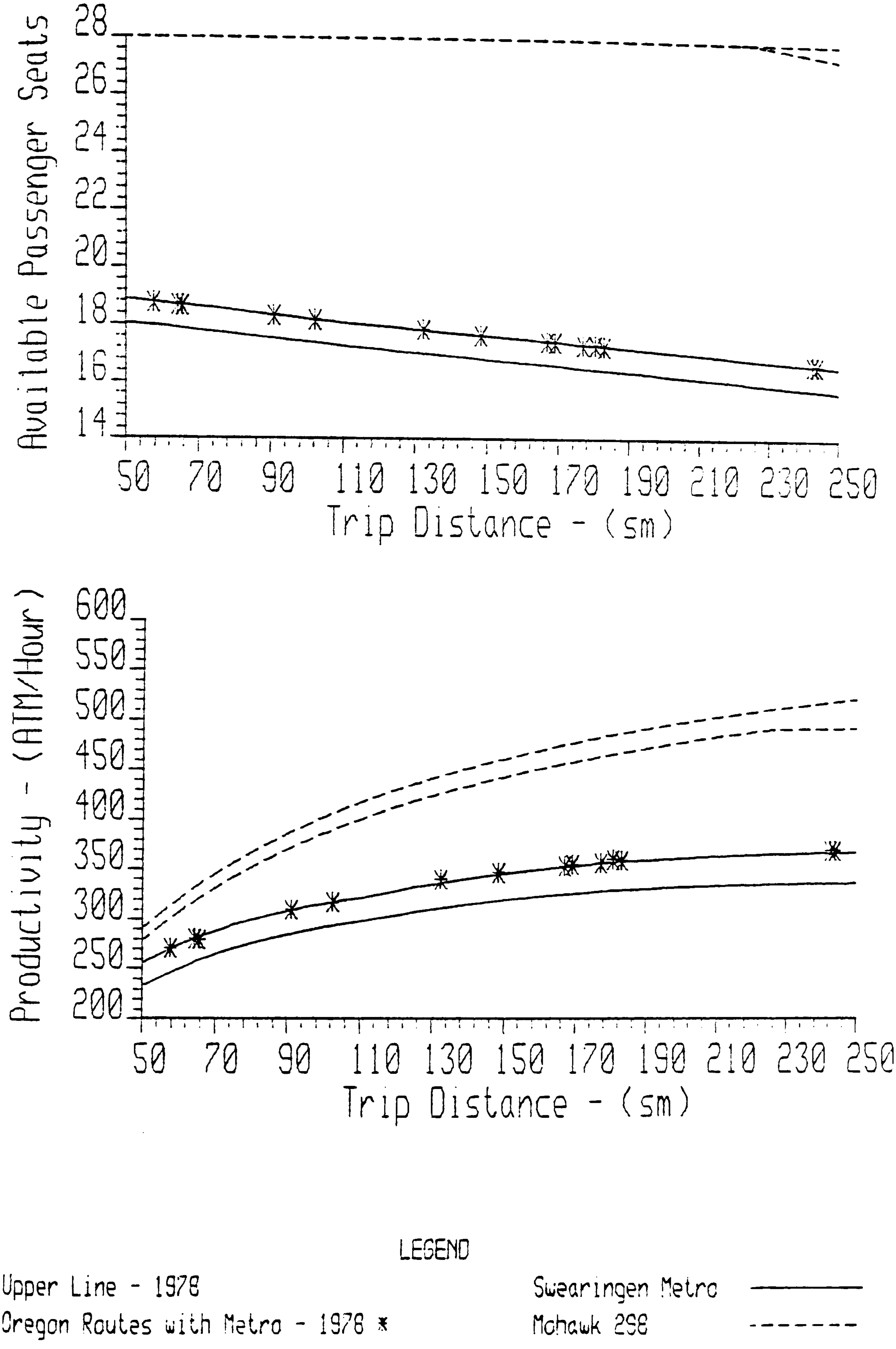


FIGURE 3-7
AVAILABLE PASSENGER SEATS AND PRODUCTIVITY VERSUS TRIP DISTANCE

TABLE 3-11

BREAKDOWN OF DOCs IN 1978 AND 1987
(1978 Dollars)

Cost Items	1978 $/Hour (%)	1987 $/Hour (%)
Aircraft	46.50 (22.5)	44.88 (20.2)
Fuel	47.90 (23.2)	57.52 (25.9)
Oil	0.23 (0.1)	0.28 (0.1)
Crew	36.12 (17.5)	44.11 (19.9)
Engineering Labor	12.61 (6.1)	12.97 (5.9)
Avionics Labor	0.99 (0.5)	0.96 (0.4)
Maintenance Burden	9.83 (4.8)	10.11 (4.6)
Material	17.20 (8.3)	17.26 (7.8)
Avionics Material	0.38 (0.2)	0.38 (0.2)
Engines	27.50 (13.3)	27.50 (12.4)
Insurance	+7.14 (3.5)	+5.75 (2.6)
TOTAL	206.40 (100%)	221.72 (100%)*

* Change in hourly cost (1978-1987): +7.3%

3.3 Indirect Operating Costs

Indirect operating costs are composed of all operating costs not associated with flight operations and all administrative costs with the exception of maintenance burden. A breakdown of indirect operating costs (IOCs) is given in Table 3-12. The breakdown is much less clear than for DOCs. It was, therefore, impossible to disaggregate the IOCs to the extent desired.

The IOCs were broken into labor, nonlabor, corporate excise and capital gains taxes, and depreciation of ground property. Labor costs are defined as wages and benefits paid to the employees of the airline. Nonlabor costs are all others. Corporate excise and capital gains taxes and depreciation of ground property were handled explicitly in the risk analysis program, Section 6.

The method of modeling is multiple regression analysis which has been used successfully in other studies.[56,57] The data is from the same four airlines.

The independent variables below were tried alone or in appropriate combinations:

1. Revenue-passenger-miles per year (including air freight)
2. Number of employees in indirect operations
3. Number of departures annually
4. Year of operation
5. Number of passengers annually
6. Unionization (dummy variable)
7. Number of aircraft
8. Number of seats per aircraft
9. Aircraft type (dummy variable)
10. Hours flown per year

3.3.1 Indirect Operating Cost--Labor

Labor cost was not directly explainable in terms of what the airline produces, e.g., available-seat-miles, revenue-passenger-miles, passengers, or departures. However, it was explainable in terms of the number of employees:

$$LC = K1 + K2\ E$$

where

LC is the labor cost in thousands of 1976 dollars,

TABLE 3-12

INDIRECT OPERATING COSTS

Passenger Service

- Interrupted trip expenses
- Baggage loss and damage
- Freight loss and damage

Aircraft and Traffic Servicing

- Scheduling
- Landing fees
- Hangar rental and maintenance
- Station rental and maintenance
- Aircraft parking and servicing

Reservation and Ticket Sales

- Reservations and sales
- Tariff development
- Schedule development
- Communications
- Commissions
- Space rental
- Ticket stock
- Employee benefits

Sales and Advertising

- Advertising
- Sales promotion

General and Administrative

- Corporate expenses
- Accounting
- Purchasing expenses
- Management salaries
- Legal fees
- Heat, light, and power
- Office supplies
- Uncollectable accounts
- Taxes
- Depreciation of ground property

K1 (-40.27770) is the intercept,

K2 (7.83673) represents the incremental cost of an additional employee in thousands of 1976 dollars, and

E is the number of employees in indirect operations.

The complete statistics are shown in Table 3-13.

A two-stage regression is required. First it was necessary to explain the number of employees in terms of what the airline produces and next to explain the airline labor costs in terms of the forecast number of employees.

The number of employees are best explained by the following equation:

$$E' = K1 \; RPM^{K2} \; D^{K3}$$

where

E' is the estimated number of employees in indirect operations,

K1 (0.000605) is the calibration coefficient,

RPM is thousands of revenue-passenger-miles per year (including air freight at 191 pound-miles per passenger-mile),

K2 (1.05328) is the exponent of revenue-passenger-miles (It is more than one indicating that in terms of number of employees and expected labor costs there are slight diseconomies of scale, but it is only 0.70606 greater than one (based on the standard error of the regression coefficient) indicating there is a 24% chance of economies of scale.),

D is the annual completed departures (000s)by the airline, and

K3 (0.38089) is the exponent of departures (it indicates economics of scale, in terms of employees, with increased departures).

The complete statistics are given in Table 3-14.

The beta coefficients for estimated number of employees are 0.82308 for RPMs and 0.28967 for departures, indicating that RPMs dominate the model.

Labor cost was then found from:

$$LC = K1' + K2' \; E'$$

where

LC is the labor cost in thousands of 1976 dollars, PADI, V.T. - 1973 - 26/120

46 DESIGN SPECIFICATION
ir an aircraft for DOMESTIC
[illegible] [illegible] AFRICA

ARNER, T.D.

A METHODOLOGY OF INVESTMENT
appraisal for third level
airlines. 2 vols PhD
1980 33/223

Bevan Clarke
CTS

TABLE 3-13

(BASED ON ACTUAL EMPLOYEES)

CT OPERATING COSTS (000'S)
EMPLOYEES

= 2

CORREL.	REG.CO.	S.E. OF R.C.	COMP. T
0.96693	7.83673	0.68903	11.37349

RRELN. 0.96693 S.E. OF ESTIMATE 83.72319

SUM SQ	MEAN SQS.	F VALUE
906732.06525	906732.06525	129.35627
63086.14883	7009.57209	

			SIDUAL
			6.23041
			6.74906
			2.55400
			4.58228
5	[illegible]	[illegible]	-62.32143
6	215.77000	234.00779	-18.23779
7	174.73300	234.00779	-59.27479
8	181.48000	234.00779	-52.52779
9	920.08100	892.29298	27.78802
10	1031.53800	1017.68063	13.85737
11	733.71000	853.10933	-119.39933

TABLE 3-14

NUMBER OF EMPLOYEES IN INDIRECT OPERATIONS MODEL

```
LOG-LOG REGRESSION OF NUMBER OF EMPLOYEES IN INDIRECT OPERATIONS
AGAINST REVENUE PASSENGER MILES (000'S) AND DEPARTURES (000'S)

CORRELATION COEFFICIENTS

  1.000  0.955  0.663
  0.955  1.000  0.454
  0.663  0.454  1.000
 MULTIPLE REGRESSION     N=  11    M=   3
 VARIABLE    MEAN       ST.DEV.      CORREL.       REG.CO.    S.E. OF R.C. COMP. T
    2      9.81047      0.42495      0.95463       1.05328      0.07546     13.95850
    3      3.27210      0.41356      0.66347       0.38089      0.07754      4.91228
 DEPENDENT
    1      4.16920      0.54380
 INTERCEPT -7.41026   MULTIPLE CORRELN.  0.93890    S.E. OF ESTIMATE  0.09034
 ANALYSIS OF VARIATION         DF         SUM SQ      MEAN SQS.       F VALUE
ATTRIB. TO REGRESSION           2        2.39194       1.44597     177.16854
DEVIATION FROM REGRESSION       8        0.06529       0.00816
CORR. MULT. CORRELN.     0.98766
AUTO-CORRELN. OF RES.    0.04559
VON NEUMANN RATIO        2.26391
HETEROSCEDASTIC CORRELN.   0.24398
HETEROSCEDASTIC T-COMP.    0.75474
  NO.       OBS.Y        EST.Y       RESIDUAL
   1       4.62497      4.48067      0.14431
   2       4.45435      4.44412      0.01023
   3       4.09434      4.13585     -0.04150
   4       3.91202      3.92781     -0.01578
   5       3.68888      3.66780      0.02108
   6       3.55535      3.68650     -0.13121
   7       3.55535      3.52669      0.02866
   8       3.55535      3.50773      0.04762
   9       4.77912      4.91617     -0.13705
  10       4.90527      4.85989      0.04539
  11       4.73620      4.70794      0.02826
ORIGINAL VALUES
  NO.       OBS.Y        EST.Y       RESIDUAL
   1     102.00000     88.29360     13.70640
   2      36.00000     35.12467      0.87533
   3      60.00000     62.54245     -2.54245
   4      50.00000     50.79548     -0.79548
   5      40.00000     39.16554      0.83446
   6      35.00000     39.90745     -4.90745
   7      35.00000     34.01119      0.98881
   8      35.00000     33.37226      1.62774
   9     119.00000    136.47923    -17.47923
  10     135.00000    129.00969      5.99031
  11     114.00000    110.82314      3.17686

MEAN DEVIATION=    4.81
```

K1' (-29.93196) is the new intercept,

K2' (7.71024) represents the new incremental cost of an additional employee in thousands of 1976 dollars ($7710.24), and

E' is the estimated number of employees in indirect operations.

Table 3-15 gives the full regression statistics.

This equation, based on the estimated number of employees, does not predict the labor costs as well as the equation based on the actual number of employees.

3.3.2 Indirect Operating Cost--Nonlabor

The equation below best explained the nonlabor indirect operating costs.

$$NLC = K1\ RPM^{K2}\ e^{K3(Y-1972)}$$

where

NLC is the nonlabor indirect operating costs in thousands of 1976 dollars,

K1 (0.128884) is the calibration coefficient,

RPM is thousands of revenue-passenger-miles per year (including air freight at 191 pound-miles per passenger-mile),

K2 (0.90372) is the exponent of revenue-passenger-miles and shows mild economies of scale (In this case, there is an 11.5% chance that diseconomies of scale exist.),

e (2.718281828) is the natural logarithm,

Y is the year, e.g., 1972, 1974, and

K3 (-0.09657) is the exponent of the natural logarithm, e, and the coefficient of time, Y-1972. It results in a decrease of 9.2% per year in real terms. This decrease with time is due to increased use of computers and better arrangements with certificated carriers, airports, and vendors. It is debatable how long this trend will continue. Evans[56] found that nonlabor IOCs for certificated carriers could be represented by an equation of identical form, but with K1 = 0.16919, K2 = 0.86600, and K3 = 0.035 and with time of the form (Y-1970). This results in a real cost increase of 3.56% per year. The two equations, ceteris paribus, give equal nonlabor indirect operating costs in May of 1972 (based on the results of Section 5). By 1976, third-level airline costs are 62% of certificated carrier costs. Because data extended through

TABLE 3-15

INDIRECT OPERATING COSTS--LABOR MODEL

```
LINEAR REGRESSION OF LABOR INDIRECT OPERATING COSTS (000'S) IN 1976
DOLLARS AGAINST NUMBER OF EMPLOYEES FOUND FROM EMPLOYEE ESTIMATION
REGRESSION

CORRELATION COEFFICIENTS

  1.000  0.956
  0.956  1.000
ORIGINAL VALUES
 MULTIPLE REGRESSION    N=  11    M=   2
 VARIABLE   MEAN       ST.DEV.      CORREL.       REG.CO.    S.E. OF R.C. COMP. T
    2    73.59483    38.61064     0.95594       7.71024      0.78927     9.76884
 DEPENDENT
    1   537.50299   311.41910
 INTERCEPT-29.93106   MULTIPLE CORRELN.  0.95594   S.E. OF ESTIMATE 96.36785
 ANALYSIS OF VARIATION          DF          SUM SQ      MEAN SQS.        F VALUE
ATTRIB. TO REGRESSION            1  886237.70758  886237.70758       95.43020
DEVIATION FROM REGRESSION        9   83580.87128    9286.76348
CORR. MULT. CORRELN.    0.95092
AUTO-CORRELN. OF RES. -0.21989
VON NEUMANN RATIO       2.55409
HETEROSCEDASTIC CORRELN.  0.17547
HETEROSCEDASTIC T-COMP.   0.53471
  NO.      OBS.Y        EST.Y       RESIDUAL
   1    775.29900    650.84940    124.44960
   2    650.43000    626.41711     24.01289
   3    432.48025    452.29785     30.18240
   4    536.14113    361.72368    174.41745
   5    210.87045    272.05098    -61.18053
   6    215.76980    277.77126    -62.00147
   7    174.73278    232.30870    -57.57593
   8    131.47995    227.38227    -45.90232
   9    920.08140   1022.38124   -102.29984
  10   1031.53802    964.78826     66.74976
  11    733.71007    324.56208    -90.85201
```

1976 and the major gains may have been accomplished, changes are expected to occur more slowly in the future; therefore, Y is set equal to 1976 in the simulation.

Table 3-16 gives the complete statistics for nonlabor IOCs.

The beta coefficients are 1.00860 for RPMs and 0.29617 for time, indicating that RPMs dominate the model.

3.3.3 Indirect Operating Cost Summary

Figure 3-8 summarizes the variation of IOCs per RPM based on 37604 completed departures per year as determined in Section 5. The variation is small which reduces the number of iterations required to find an accurate and optimum solution. The other determinant of IOCs is departures. Departures are considered uniquely determined by the schedule, mechanical reliability, and meteorology (Section 5.3.4.1). For nonlabor, the year is presumed to be 1976 and the remaining effects are all due to RPMs.

TABLE 3-16

INDIRECT OPERATING COSTS--NONLABOR MODEL

LOG-LOG REGRESSION OF NON-LABOR INDIRECT OPERATING COSTS (000'S) IN 1976 DOLLARS AGAINST REVENUE PASSENGER MILES (000'S) AND EXPONENT TIME

CORRELATION COEFFICIENTS

1.000	0.927	-0.019
0.927	1.000	0.275
-0.019	0.275	1.000

MULTIPLE REGRESSION N= 11 M= 3

VARIABLE	MEAN	ST.DEV.	CORREL.	REG.CO.	S.E. OF R.C.	COMP. T
2	9.81047	0.42495	0.92722	0.90372	0.08014	11.27638
3	2.18182	1.16775	-0.01900	-0.09657	0.02916	-3.31132
DEPENDENT						
1	6.60636	0.38076				

INTERCEPT -2.04384 MULTIPLE CORRELN. 0.96996 S.E. OF ESTIMATE 0.10355

ANALYSIS OF VARIATION	DF	SUM SQ	MEAN SQS.	F VALUE
ATTRIB. TO REGRESSION	2	1.36400	0.68200	63.60281
DEVIATION FROM REGRESSION	8	0.08578	0.01072	

CORR. MULT. CORRELN. 0.96230
AUTO-CORRELN. OF RES. 0.05621
VON NEUMANN RATIO 1.87248
HETEROSCEDASTIC CORRELN. 0.43336
HETEROSCEDASTIC T-COMP. 1.44256

NO.	OBS.Y	EST.Y	RESIDUAL
1	6.73200	6.78747	-0.05546
2	6.32827	6.46202	-0.13375
3	6.35273	6.37154	-0.01881
4	6.32236	6.28777	0.03458
5	6.35312	6.22479	0.12834
6	6.39769	6.36213	0.03556
7	6.31870	6.34035	-0.02165
8	6.37441	6.42351	-0.04910
9	7.28602	7.13487	0.15115
10	7.01996	7.14838	-0.12842
11	7.18467	7.12710	0.05757

ORIGINAL VALUES

NO.	OBS.Y	EST.Y	RESIDUAL
1	838.82700	886.66673	-47.83973
2	560.18400	640.35124	-80.16724
3	574.06000	584.95879	-10.89879
4	556.88300	537.95486	18.92814
5	574.28300	505.11533	69.16767
6	600.45500	579.47749	20.97751
7	554.85200	566.99577	-12.14377
8	586.63900	616.16318	-29.52418
9	1459.75400	1254.97495	204.77905
10	1118.74600	1272.04869	-153.30269
11	1319.05600	1245.26567	73.79032

MEAN DEVIATION= 65.59

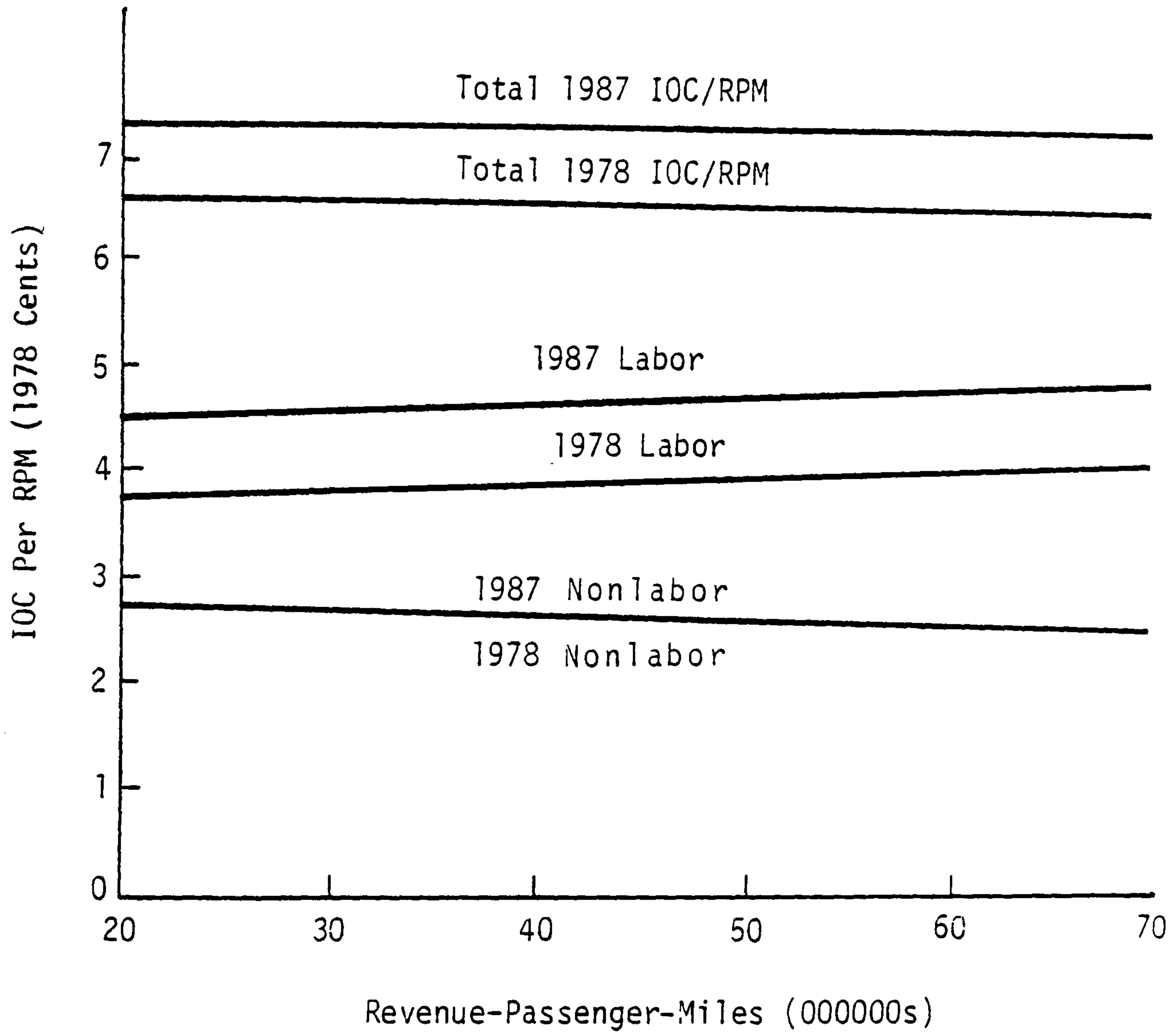


FIGURE 3-8
INDIRECT OPERATING COSTS VERSUS REVENUE-PASSENGER-MILES

4. MAINTENANCE

4.1 Introduction

This section reviews current third-level airline maintenance practices and shop facilities. It analyzes the hard-life versus the on-condition philosophy, investigates initial spares provisioning, and develops the "affordable risk" concept for reserve aircraft and for determining the service level of other major spares (engines and avionics). Rate Per Hour Contracts are investigated from the viewpoint of the small operator. And, new formulae for reliability guarantees that include the cost of capital and the time value of money are developed.

4.1.1 The Goal of Maintenance

The goal of maintenance is to maximize the contribution made to the firm by an item of capital equipment throughout its economic life. This is consistent with the other objectives of airline maintenance: improving equipment safety and reliability, and obtaining, maintaining, and disposing of equipment in such a manner as to minimize the cost per unit of productivity. Third-level airlines have developed appropriate maintenance organizations to meet this goal.

4.1.2 Current Third-Level Maintenance Practices

The following provides an overview of third-level maintenance organizations and practices against which investment decisions must be viewed. (For an explanation of maintenance concepts, see Appendix G.)

The shop supervisor and operations manager do all production planning. Third-level airlines normally do 80% of their maintenance between 10 pm and 6 am. A progressive or equalized maintenance system is used because the airlines are too small to realize any manpower savings from a pyramidal system. Their relatively new equipment and short-haul route structure also favors the equalized concept. The "two eyes" system of inspection (one mechanic checking another) is employed rather than designated inspectors or quality control engineers. Nearly all items on the aircraft are on-condition with the exception of engine hot-sections and, occasionally, propellers.

Third-level maintenance organizations normally repair airframe components and subsystems. Items such as starter-generators, inverters, voltage regulators, synchronizers, gear actuators, trim actuators, hydraulic pumps, fuel pumps, air conditioning subassemblies, tire recaps, and brake assemblies are often contracted. Operators will usually send out a major airframe repair requiring extensive jigging. The airlines do major engine repairs and hot-section inspections, but do not overhaul or repair the inner core or turbine; except Ransome Airlines, operating Aerospatiale Fregates, who find it more economical to overhaul the Turbomeca than to return it to France. About one-half test and repair avionics, but few maintain their own pulse equipment. All operators contract out the repair and overhaul of gyro and pressure instruments. Airlines do not generally take outside airframe or engine work into the shop and less than one-half take in outside avionics work.

The airlines use ultrasonics, boroscopes, dye penetrants, and Alco-probes in-house for nondestructive testing, but radiography (X & Y), eddy current, thermal, and acoustic methods are contracted because of high equipment costs and skilled labor requirements.

Third-level operators have found factory modifications uneconomical and do only mandatory modifications. They do not pool spares though Ransome Airlines, as a foreign aircraft operator, would like to start. Operators do not hold insurance items or large spares inventories. They are satisfied with the speed of support, but they have found that speed of support is proportional to the speed of payment.

Manufacturers will rob production-line aircraft if an out-of-stock part is needed. They give discounts of up to 80%, but 25-40% is normal on parts bought factory-direct. Engine overhaul agencies also give scheduled operators discounts of up to 20%. Manufacturers have begun supplying technical representatives for airframes and engines for up to six months with the purchase of a new aircraft type in quantities of four or more. The technical representatives cut unverified failures from 40-50% to 20-25% in the early operation of a new aircraft type.

4.1.2.1 Plant And Equipment

Maintenance requires a hangar area of 10000 to 12000 square feet and an additional area of 3750 square feet apportioned general shops, 2000 square feet; stores, 950 square feet; offices, 500 square feet; and avionics shop, 300 square feet. The shop and hangar can be purchased for $18 to $24 per square foot or, as is more common, older hangars owned by the airport authority are leased for $0.10 to $0.16 per square foot per month. The average value of equipment is airframe, $100000; engine, $50000; and avionics, $60000 (when the work is done in-house).

4.1.3 Potential Benefits from Maintenance Analysis

The airframe, engines, and avionics may be considered as separate systems for support purposes. It has been estimated that control of spares and maintenance of propulsion units results in an order of magnitude (10) savings over airframe systems (1), and even more over electrical systems (0.5). But in labor assignment savings, the airframe offers 50% more opportunities than propulsion.[58]

After the removal of the engines and avionics, the airframe consists of many heterogeneous items having generally low failure rates and relatively low costs. There are exceptions for specific items, but the airframe components do not represent a significant or controversial area for a first-order analysis. Additionally, many airframe components are consumable and offer the opportunity for a posteriori adjustment. In short, the resources consumed in a detailed analysis of airframe components may never be justified by the savings achieved.

Engines spares are a major investment with high stockholding costs. Engine maintenance expense is primarily for major overhauls which require specialized personnel. There are several competing firms specializing in engine overhauls. Therefore, analysis offers the prospect of significant savings.

Avionics have a high failure rate, are of moderate value, require one or two specialized people for repair, and require a significant investment in test equipment. About one-half the third-airlines repair their own avionics which indicates that an analysis might be helpful.

Appropriate shop equipment must be purchased for the items the airline plans to repair. Shop equipment was defined and costed with the help of the Cranfield Engineering and Avionics Shops, Appendix H. Office equipment consists of many different low-value items; therefore, it is inappropriate for detailed analysis.

4.2. Analysis of the Hard-life Versus the On-Condition Philosophy

A study done by the National Transportation Safety Board in 1972,[59] which groups third-level carriers along with all other general aviation and air taxi, recommends, nonspecifically, that all operators should have more hard-life items and fewer on-condition items. This recommendation is investigated below in terms of the past experience of certificated carriers.

Maintenance philosophy and spares investment are both functions of the changing failure rate of a rotable or recoverable component with time. Historically, airline maintenance has been based on a belief that a component will follow a bathtub-shaped failure-rate curve where high infant mortality is followed by a relatively long period of constant failure rate after which the failure rate increases with age as the component wears out. The component is removed when the risk of failure is too great. Component life is generally expressed in terms of flight hours or flight cycles and termed "hard-life" because of its inflexibility.

A United Airlines study[60] showed this philosophy suspect because:

1. There was no optimum overhaul time for most, if not all, components.

2. Overhauling at a computed optimum overhaul time did not have much effect on reliability.

3. It was impossible, even with the flexibility permitted by Advisory Circular 120-17, to determine the optimum overhaul time in a statistically correct, quick, and economical manner.

This implies that failure rates do not increase significantly with age. This caused United to cease approaching the aircraft as if they possessed a priori knowledge and to approach it instead in a totally exploratory manner.

A survey, similar to the one done by United, was performed with the help of U.S. trunk airlines (4 respondents). The results are shown in Table 4-1.

TABLE 4-1

SPARES VALUE AND NUMBER BY TYPE AND FAILURE PROFILE

Spare Type	Airframe Structure	Airframe Systems	Powerplant Minus Hot-Section	Powerplant Hot-Section	Engine Systems	Total Investment
Failure Profile	13%	45%	10%	23%	9%	100%
A		33.3% (74%)				33.3%
B	10.4% (80%)	6.3% (14%)	10% (100%)	23% (100%)	9% (100%)	58.7%
			7%* (70%)*	6.9%* (30%)*	4.5%* (50%)*	35.1%*
C		2.7% (6%)				2.7%
D		2.7% (6%)				2.7%
E						
F			3%* (30%)*	16.1%* (70%)*	4.5%* (50%)*	23.6%*
Indeterminate	2.6% (20%)					2.6%

( ) is the percentage of the total number of spares
* is the first five years of engine operation

NOTE--Engine shop visits normally only restore the part needing immediate attention. This has a tendency to re-enforce the randomness of engine failure.

Failure profiles for Table 4-1 are shown in Figure 4-1 and explained below.[60]

(A) Infant mortality followed by a constant or slightly increasing failure rate (λ).

(B) Constant failure rate.

(C) Low failure rate in infancy followed by an increasing failure rate that rapidly becomes a constant failure rate.

(D) A gradually increasing failure rate.

(E) A constant or slightly increasing failure rate followed by wearout characteristics.

(F) Infant mortality followed by a constant or gradually increasing failure rate and finally wearout characteristics (the bathtub curve).

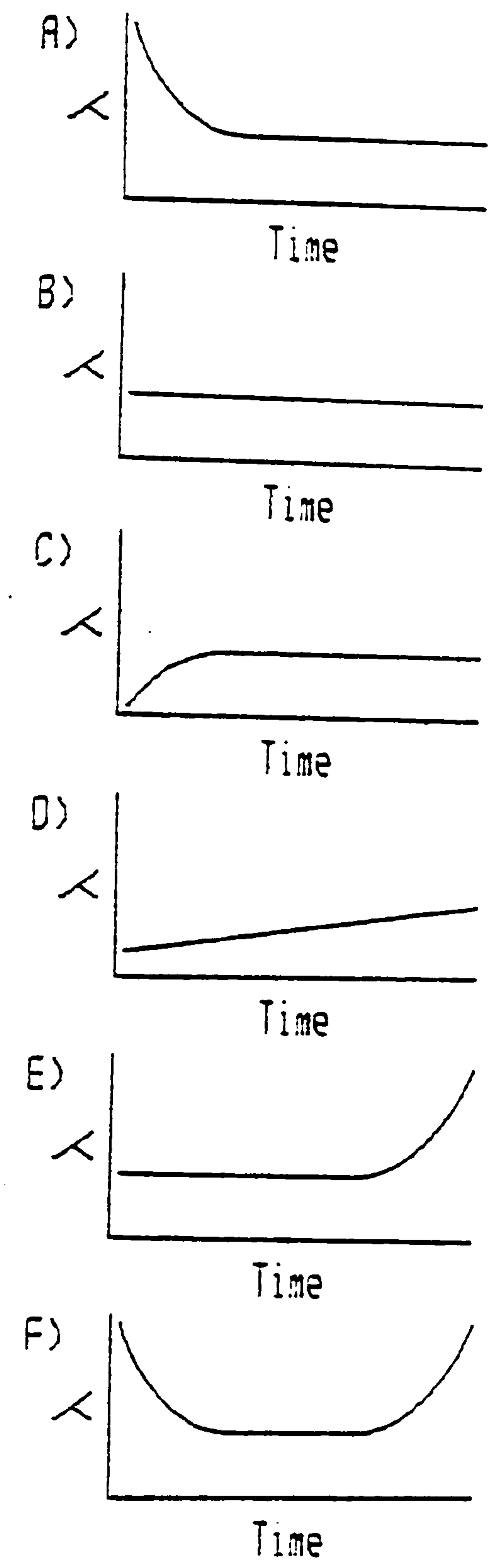


FIGURE 4-1
FAILURE PROFILES

A hard-life policy is damaging to profile A items, 33% by value, and has no effect on profile B and C items, 61.4% by value (mature engines), or 37.8% by value (immature engines). This suggests that with mature engines 94.4% by value of an airline's rotables and repairables should be maintained on-condition and that only 5.6% by value will benefit from a hard-life philosophy.

To overhaul an item when it requires overhaul and after a set period is bound to be more expensive than if the overhaul is just done on-condition.

4.3 Spares Investment Criteria

Spares investment is determined by:

1. The revenue generated.

2. Spare cost including stockholding cost. Third-level spare holdings run from $250000 to $650000 for aircraft in production and $1200000 to $1600000 for aircraft out of production. Stockholding costs are given in Table 4-2.[61] Another item that should be included in the stockholding cost is the airline's cost of capital. The stockholding cost is assumed to be 8% and the cost of capital is assumed to be 13%, for a total of 21% per annum. In this analysis, the two costs are kept separate.

3. Fleet size, age, commonality, and intensity of utilization.

TABLE 4-2

STOCKHOLDING COSTS

Stockholding Costs	% of Investment
Insurance	1-1.5
Storage	2-3
Calendar Deterioration	1-2
Obsolescence	1.5

Range of Stockholding Costs	5.5-8%

4. Component removal and rework policy.

5. Component necessity--aircraft can never/sometimes/always be dispatched without the unit.

6. Technical statistics--Time-Between-Overall (TBO) for hard-life items, Mean-Time-Between-Unscheduled-Removal (MTBUR), Mean-Time-To-Repair (MTTR) off aircraft, failure rate as a function of time, and sampling requirements for on-condition items.

7. Out-of-service time allowance.

8. Facilities (computer, etc.) for spares analysis and update.

"Spare" shop labor for dealing with unscheduled maintenance is also a function of items 1. through 6. above. Shop labor allocation in third-level operations was found to be 55-60% for scheduled maintenance, 15-20% for unscheduled work, and 20-25% unallocated.

Spare investment must be balanced against the costs of cancellation:

1. Projected loss of revenue because the passenger moves to a competitor or another mode of transport.

2. The expense of providing food and lodging for the stranded passenger.

3. Repositioning aircraft to avoid schedule disruption.

4. Unrecoverable administrative costs, e.g., reservations, baggage handling, customer service, lost crew time.

5. Intangible costs, e.g., long-term passenger, Civil Aeronautics Board, and Federal Aviation Administration reaction.

4.3.1 Initial Provisioning

The initial provisioning policy should take into account the short-term uncertainties and the long-term costs. Therefore, initial provisioning should do the following:

1. Obtain a wide range of potentially useful items. This will provide coverage as the learning curve develops.

2. Procure initial items to a minimum depth. Experience has shown that only about ten percent of all airline parts develop a sustaining spares requirement.[43]

3. Distribute this "minimum depth" to all maintenance locations, rather than holding it at the major repair base. Initially, field stations have the highest requirement for maintenance material and that need may persist for an on-condition airplane. Normally, this would be inapplicable to a third-level airline as there are no field stations.

A survey of U. S. trunk airlines (4 respondents) showed the build up, with fleet-size effects removed, of spares investment given in Table 4-3. The answers received did not take into account the development of the aircraft type by other operators prior to the respondents acquiring it.

The U. S. trunk airlines (6 respondents) were also queried as to how this money was invested in spares. One third-level manufacturer also gave a recommended breakdown in both dollars and number of items (Table 4-4).

4.3.2. Line Station Spares and Equipment

Appropriate spares should be kept at line stations. Line stations should stock a main wheel with an installation kit and isopropyl alcohol for surface de-icing. Line stations with a high frequency of operations should also stock a spare VHF navigation and communication unit. Where the work will require a licensed mechanic, he will have to be trained by the airline.

4.4 Determining the Service Levels of Major Spares

This section addresses the following questions concerning spares investment: the affordable risk concept, the reserve aircraft problem, and the service level required from the engine pool.

4.4.1 The Affordable Risk Concept

"Affordable Risk", AR, is the amount of risk a company should accept in its effort to maximize its expected profit. Affordable risk is quantifiable from such basics of the cost-revenue process as revenue (volume multiplied by unit price), R; fixed costs (the annual cost of investment, costs independent of production), C; variable costs (the marginal cost of production), V; and, opportunity costs (the tangible cost resulting from the inability to supply demand and the intangible costs of insufficient capacity), S. Intangible opportunity costs (Section 4.3) are nearly impossible to determine; being optimistic, they are assumed to be zero. The tangible component of S may now be expressed in terms of R, V, and C (Appendix I). Using the above, contribution is defined by:

$$\text{Con} = R-V-C$$

and, affordable risk is defined by:

$$AR = \frac{C}{2(R-V) - C}$$

or

$$AR = \frac{C}{2\ \text{Con} + C}.$$

TABLE 4-3

SPARES INVESTMENT SCHEDULE

Time	Mean	Range
First Year	62%	40-85%
Second Year	77%	48-94%
Third Year	92%	80-99%
Fourth Year	99%	90-100%

TABLE 4-4

SPARES INVESTMENT BREAKDOWN

Type of Spares	Airlines Mean ($)	Airlines Range ($)	Third-Level Manufacturer ($)	Third-Level Manufacturer (#)
Fully Rotable	53%	45-60%	65%	24%
Repairable & Recoverable	19%	10-31%	16%	20%
Expendable	27%	15-45%	19%	56%
Insurance Items	1%	0-5%	0%	0%

Mathematically there are values of R-V or Con that won't work, but these are negative profit situations and would be eliminated anyway. A complete proof of affordable risk is given in Appendix I.[62]

It is important to note that when contribution equals zero affordable risk equals one indicating no risk should be assumed, i.e., the chance of making the projected contribution must be 100% (the investment breaks even). The affordable risk increases (approaches zero) as either the contribution increases or the annual cost of owning the investment decreases.

The concept can be extended to spares provisioning, but now the annual fixed cost of ownership, C, is that of the spare and the variable costs, V, are those that are short-term variable (escapable). The Revenue, R, produced by the investment is unchanged.

The short-term variable costs are determined from the accounts of third-level airlines and are shown in Table 4-5. The percentages are then applied to the 1978 quantitites (Table 5-24).

4.4.2 Reserve Aircraft

The analysis is given in Table 4-6. The affordable risk formula works, but there are problems with the analysis:

1. Two aircraft are assumed in scheduled maintenance during scheduled flying hours. This is necessary to bring aircraft utilization in line with the industry. This assumption makes the results of the analysis less clear.

2. If the remaining aircraft can be shifted to the routes providing the best contributions, the effective contribution of the out-of-service aircraft decreases increasing the affordable risk.

3. The fraction of revenue serviceable by a reserve aircraft is difficult to determine. It is a function of the time to position the reserve aircraft, the availability and characteristics of other modes, the passenger's characteristics, the type of journey, and the time of day.

4. The mechanical reliability may vary over the life of fleet. The solution is sensitive to this variable.

5. The elasticity of reliability may vary over the life of fleet. The solution is sensitive to this variable.

6. It will be difficult to ensure that the maintenance organization keeps the reserve aircraft ready for dispatch and does not use it to relieve its own difficulties, i.e., it is to be a reserve aircraft, not an aircraft in the shop.

TABLE 4-5

SHORT-TERM VARIABLE (ESCAPABLE) COSTS

DIRECT EXPENSES	
FLIGHT OPERATIONS	
Fuel & Oil	23.3%
Crew (F(RPM))	8.1%
MAINTENANCE COSTS F(RPM & FLIGHT TIME)	
Outside Services Materials Airworthiness Provisions	26.4%
INDIRECT EXPENSES F(RPM & DEPARTURES)	
Fuel & Oil For Ground Equipment Landing Fees Passenger Food Expense Baggage Claims Interrupted Trip Expenses	17.6%

TABLE 4-6

RESERVE AIRCRAFT

Assumption: Mean airline route, i.e., time of failure gives no opportunity to choose the least profitable route.

$$AR = \frac{C}{2F(R - V_s) - C}$$

where

AR is the affordable risk or the complement of the service level,
C is the annual cost of aircraft ownership,
R is the revenue per aircraft per year,
V_s is the short-term variable (escapable) cost, and
F is the mean fraction of traffic serviceable with an aircraft out of commission.

$$AR = \frac{100430}{2(0.8)(993875-471521) - 100430}$$

$$AR = 0.1366 = 13.66\%$$

$$\text{Weighted Elasticity} = \frac{3.59346 \log(\text{Local Traffic Revenue}) + \log(\text{Connecting \& Freight Revenue})}{\log(\text{Local Traffic Revenue}) + \log(\text{Connecting \& Freight Revenue})}$$

Reliability Effects:

Weighted Elasticity = 2.27366

Aircraft Reliability (A) = 98.5% = 0.985

Effective Reliability (ER) = $(0.985)^{2.27366}$ = 0.9662 = 96.62%

Complement of Effective Reliability (CER) = 1-0.9662 = 0.0338

TABLE 4-6

RESERVE AIRCRAFT
(Concl'd)

Scheduled Fleet Size (SFS) without a Reserve Aircraft: $SFS = \frac{\log(1-AR)}{\log(ER)} = 4.3$ Aircraft

Using the Binomial Distribution the SFS required to justify a second reserve aircraft may be found from:

$$\text{Service Level} = 1-0.1366 = 0.8634 = (ER)^{(SFS+1)}+(SFS+1)(CER)(ER)^{(SFS)}$$

The required service level is not exceeded until SFS exceeds 18 aircraft (Service Level = 0.8662 @ 18)

Percentage of time a flight must be cancelled for lack of a reserve aircraft:

$$1-[(A)^{(SFS+1)} + (SFS+1)(1-A)(A)^{(SFS)}] = 0.0075 = 0.75\%$$

Mean fraction of traffic serviceable with aircraft failure to justify a reserve aircraft:

$$F = \left[\frac{C}{1-(ER)^{SFS}} + C\right] \div [2(R-V_s)] = 0.496 = 49.6\%$$

Given an SFS of 8 the lower limit of aircraft reliability for which one reserve aircraft is sufficient may be found from:

$$0.8634 = (ER)^9+9(1-ER)(ER)^8$$

The required ER is 0.927, which yields the required lower limit of acceptable aircraft reliability:

$$\text{Lower Limit of Acceptable Aircraft Reliability} = \sqrt[2.27366]{0.927} = 0.967 = 96.7\%$$

4.4.3 The Service Level for Engine Spares

The service level is the complementary function of affordable risk which is then adjusted for the elasticity of reliability. The annual cost of engine ownership is computed in Table 4-7. The service level for engine spares is computed in Table 4-8. The service level may differ in practice for several reasons:

1. If the airline were to be short of aircraft they would try to abandon the least productive route(s) first, and the annual revenue earned on the least productive route(s) would be used in the formula.

2. The elasticity of reliability in the short-term may be different from that in the long-term.

3. The real cost of engines may be rising; therefore, the service level, ceteris paribus, would be less in the future than at present. In practical terms, this means that while today's service level should be purchased, only tomorrow's service level should be maintained.

4.4.4 The Engine Requirement Simulation Program

Once the service level is established, it is necessary to find the number of engines required to meet it. A computer program was written using the "Simulation Program Generator" developed by Wolf Schroeder at Cranfield Institute of Technology to simulate the engine spares requirement of a third-level airline(s) flying 20000 hours per year. Antithetic sampling was employed.

Third-level operators, manufacturers, and engine overhaul agencies in the United States were unable to supply actual calendar repair times, but they did confirm a constant failure rate (Figure 4-1--Failure Profile B and Table 3-2). British Airways repair data for the Garrett AiResearch auxiliary power unit were used to generate the log-normal distributions of repair times. This is the same basic unit as used on the Swearingen Metroliner II. Repair times of 1 and 2 days were removed from the data as being accomplished in-house by the airline.

The following assumptions were used in the computer simulation program:

1. It took one day to remove or mount an engine.

2. The hot-section overhaul rate was every 2000 hours, $\lambda = 0.0005$.

3. The engine overhaul rate was every 4000 hours, $\lambda = 0.00025$.

4. The combined engine overhaul and hot-section repair rate was every 1333.3 hours, $\lambda = 0.00075$.

5. The mean shipping time by air was log-normally distributed thus:

μ logs = 0.7110 ($\cong$2 days), and
σ logs = 0.9810.

TABLE 4-7

COST OF ENGINE OWNERSHIP

ASSUMPTIONS

Project Life	: 10 Years
Cost of Capital	: 13%
Depreciation	: Sum-of-the-Years'-Digits, 7 Years
Residual	: 10%
Resale Value	: 45%
Investment Tax Credit (ITC)	: 10%
Tax Rate	: 52%
Capital Gains Tax Rate	: 50%
Engine Cost	: $103594
Stockholding Cost	: 8% Per Year

PRECALCULATIONS

Cumulative present value factor, 10 years @ 13%	: 5.426
Present value factor, 10 years @ 13%	: 0.2946
Net-present-value of depreciation @ 13%	: 0.7081
Depreciable portion of engine (100%-10%)	: 90%
Taxable capital gains (45% - 10%)	: 35%

CALCULATIONS

Engine Cost		103594	
STOCKHOLDING COST			
Engine Cost	103594		
Stockholding Rate	X 0.08		

Stockholding Cost	8288		
CUM PV Factor	X 5.426		

PV of Stockholding		+ 44968	

PV of Engine Costs			(148562)
TAX CREDITS			
INVESTMENT TAX CREDIT			
Engine Cost	103594		
ITC Rate	X 0.10		

Investment Tax Credit		10359	

TABLE 4-7
(concl'd)

COST OF ENGINE OWNERSHIP

DEPRECIATION			
Engine Cost	103594		
Depreciable Fraction	X 0.90		
Depreciable Amount	93235		
DEP PV Factor	X 0.7081		
PV of deprec. before tax	66017		
Effective tax rate	X 0.52		
PV of depreciation after tax		34329	
RESIDUAL VALUE			
Engine Cost	103594		
Residual	X 0.10		
Residual Value	10359		
PV Factor	X 0.2946		
PV of Residual		3052	
CAPITAL GAINS			
Engine Cost	103594		
Fraction Subject to Tax	X 0.35		
Taxable Amount	36258		
Retention Rate	X 0.50		
After Tax Savings	18129		
PV Factor	X 0.2946		
PV of Gain Less Residual		+ 5341	
PV of Tax Credits			+ 53081
NET-PRESENT-VALUE OF ENGINE OWNERSHIP			(95481)
ANNUAL VALUE OF ENGINE OWNERSHIP			
Net Present Value of Engine Ownership			(95481)
CUM PV Factor			÷ 5.426
ANNUAL VALUE OF ENGINE OWNERSHIP			(17597)

TABLE 4-8

ENGINE SERVICE LEVEL

$$SL = 1 - \frac{CE}{2(R - V_s) - CE}$$

where

SL is the service level

CE is the annual cost of engine ownership

R is the annual revenue of aircraft

V_s is the short-term variable costs

$$SL = 1 - \frac{17597}{2(993875 - 471521) - 17597}$$

$$SL = 0.9829$$

Service level adjusted (SLA) for elasticity of reliability:

$$SLA = \sqrt[2.27366]{0.9829} = 0.9924$$

Allowable time without engine = 1 - 0.9924 = 0.0076 = 0.76%

6. The mean time to overhaul engines was log-normally distributed thus:

μ logs = 2.7766 (≅16 days), and
σ logs = 0.6917.

7. The mean time to do the hot-section or overhaul the engine and remount it was log-normally distributed thus:

μ logs = 2.6438 (≅14 days), and
σ logs = 0.6806.

The log-normal distribution does not have the additive-regenerative property; a variable which is the sum of two or more log-normally distributed variables is not log-normally distributed. Hence, it was necessary to explicitly designate the shipping distribution.

Four situations are investigated and illustrated in Figure 4-2A and Figure 4-2B; Figure 4-2B is a 10:1 enlargement of the ordinate of Figure 4-2A:

Curve 1. The current situation. The overhaul agency only does engine overhauls and there is no exchange agreement. It is simulated over 92000 days or over 250 years of airline operation.

Curve 2. The overhaul agency does all major maintenance and there is no exchange agreement. It is simulated over 92000 days or over 250 years of airline operation.

Curve 3. Three airlines have a spares pool and there is no shipping time allowance. It is simulated over 37000 days or over 100 years of three-airline operation.

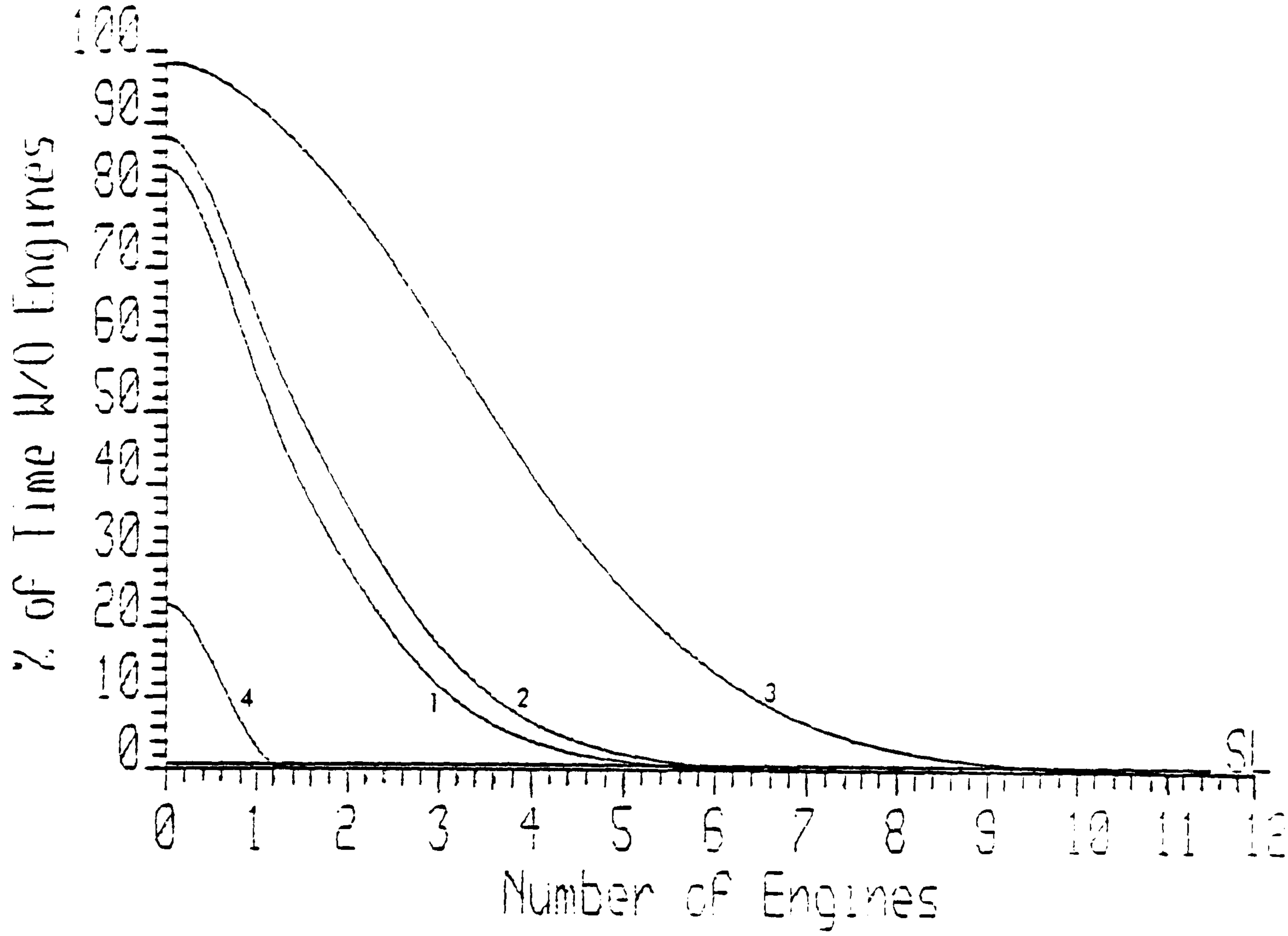
Curve 4. The time to ship an engine one-way. This supplements the situation in Curve 3. It is simulated over 92000 days or over 100 years of airline operation.

The most noteworthy items are that:

1. While the failure rate triples between curves 1 and 2, the mean-time-to-repair drops by only two days (12%) and the extra engines required is only 0.5. This indicates that the engine requirement is dominated by the turnaround time and the failure rate has little effect. A smaller airline would no doubt find failure-rate effects more significant.

2. The profiles developed from British Airways data indicated approximately one more engine (25%) should be held than is being held in practice. While third-level operators do not plan on the basis of a simulation program or an affordable risk formula, these methods should prove what occurs in practice. There are reasons why the answers might not agree exactly with practice:

a. British Airways bases overhauls on 308 man-hours per engine and 180 man-hours per hot-section. U.S. engine



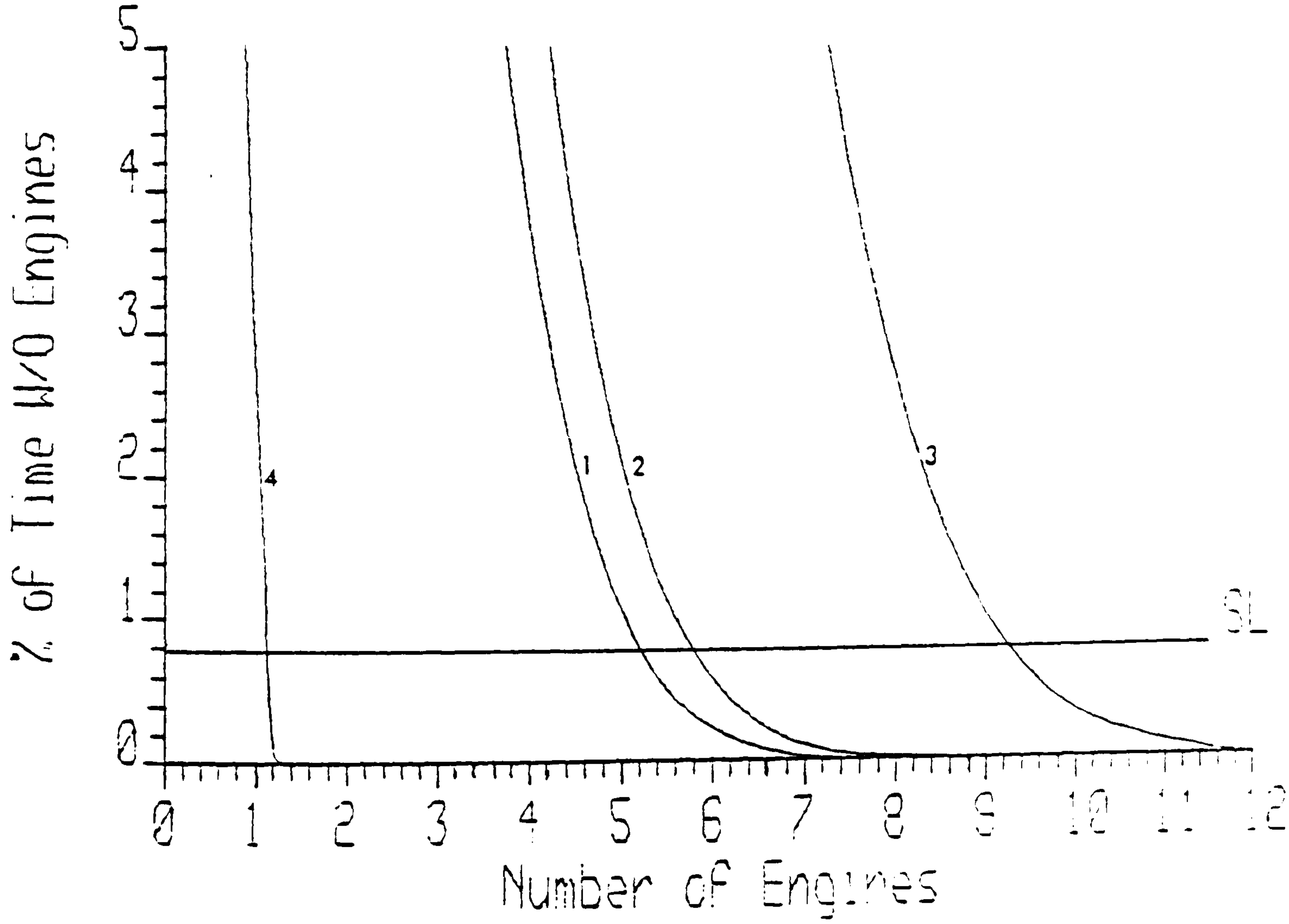


FIGURE 4-2
ENGINE SIMULATIONS

overhaul agencies give figures of 200 to 250 man-hours per overhaul and 110 man-hours per hot-section. While man-hours are different from calendar days, there should be some correlation.

b. U.S. engine overhaul agencies will guarantee a 30-day turnaround for overhauls exclusive of shipping, but recommend at least one week each way for shipping. Operators say turnarounds take 60-90 days. In the simulation, 30 days is exceeded only 17.62% of the time. The exact situation is, therefore, somewhat indeterminate, but these differences would require that even more spare engines be held.

c. The service level could be less than indicated; the allowable time without an engine would then increase.

d. Taking the elasticity of reliability as one (1) would reduce the difference.

e. Engine time-between-overhauls and hot-section time limits are increasing 10% to 20% per year. With engine overhaul requirements falling and an uncertain economic climate, operators may have found it prudent to plan for lower service levels.

4.5 Rate Per Hour Contracts for Major Spares

The Rate Per Hour Contract (RPHC) is an economical method of rotable and repairable recovery available to the small operator. It is a Rate Per Hour Contract because the operator pays the vendor a flat rate for each hour flown. There is no reason the contract cannot be based exclusively on cycles (Rate Per Cycle Contract) for appropriate items such as tires, flap and gear actuators, brakes, engine starters, etc. Or, a combination of both flight-time and cycle charges in which case the contract effectively becomes a Rate Per Flight Contract. An operator would normally try to place those items that require specialized manpower and equipment, large shop areas, high power, and exotic material, or have a low turnover or profit margin on a RPHC. Items suitable for a RPHC are shown in Table 4-9.[63]

RPHCs work well for hard-life items, but are particularly good for on-condition items with progressive (equalized) maintenance. The following description of the obligations of the vendor and the airline is based on lectures by K. J. Anderson, Economics and Systems Manager, British Caledonian Airways at the Cranfield Institute of Technology in 1975 and 1976.

Under the contract the vendor:

1. Overhauls and repairs all covered units. This makes the contract similar to a continuous warranty with the vendor providing 100% service and support. The only limitation would be with an airframe contract (which is probably inappropriate for most third-level operators). Jobs such as unforeseen fuselage cradle and wing spar failures and major airworthiness directives

TABLE 4-9

ITEMS SUITABLE FOR A RPHC IN THIRD-LEVEL OPERATIONS[63]

Engine	Fuel Control
Starter	Fuel Pumps
Generator	Propeller
Inverters	Hydraulic Pumps
Synchronizers	Brake Assemblies
Avionics	Tire Recaps
Air Conditioning	Gyro Instruments
Pressure Instruments	

would need to be placed under an exclusion, perhaps in terms of a job-time limit or turnaround-time relief. The vendor should agree not to return any covered item or accessory without a specified amount of time-, cycles-, or flights-to-overhaul remaining on it. Accessories should have the same time remaining on them as the main unit, particularly if the airline is prohibited from removing and replacing the accessory under the terms of the contract. If the vendor is the manufacturer, he should pay for all mandatory safety modifications and campaign changes. The airline pays extra for damage by foreign objects, misuse, or negligence. The repair of an item by an unauthorized repair station could constitute misuse. If a nonfailed unit is returned for overhaul with more than a specified time remaining, the operator should pay to the specified overhaul time. If the item has less than a specified amount of time remaining on it when it is sold, the vendor should prorate the time at an agreed percentage.

2. Modifies units as he sees fit to give an increased Time-Between-Overhaul (TBO) and/or Mean-Time-Between-Maintenance-Action (MTBMA); the only restriction being that modification(s) cannot affect interchangeability. The burden of evaluating the modification is placed on the vendor who will have to evaluate each contracted operator's situation in light of their mutual experience. If the vendor is the manufacturer, his state of knowledge of the product will generally be two to three years ahead of the airline enabling him to make perceptive analyses of modifications and performance. He can also advise the airline on the best lubricants, seals, fluids, bearings, polymers, and other items which the airline is authorized to remove and replace.

3. Replaces all units that, in his estimation, are beyond economic repair.

4. Gives a guaranteed turnaround for each unit not covered by an exchange agreement. With an exchange agreement, the vendor must provide an appropriate spares pool--covered components are available on demand. In any case, the turnaround time will fix the operator's float. A "first-service agreement" could be negotiated, though this would be unnecessary with an exchange agreement.

5. Charges a test fee for all nonfailed units. This will quickly highlight an operator's maintenance mistakes.

6. Pays outbound transportation and is responsible for outbound shipping losses.

7. Is responsible for his overtime and any outbound express shipping required.

8. Incurs a moral obligation to tell the airline if any non-covered components are nearing failure.

The vendor receives in consideration:

1. A guaranteed income which can be adjusted over the life of the contract. Payment should be made monthly on the basis of actual or anticipated usage with quarterly rectification and update of discrepancies. This prompt, monthly cashflow is a major inducement to the vendor and, as airlines have noted (Section 4.1.2), results in prompt support. The airline also agrees to fly a minimum amount of time (cycles or flights) per year or pay accordingly. It may be advisable to break the charges (time, cycle, or flight) into labor and material components, then each could be adjusted fairly over the life of the contract. The material cost should be adjusted by the Wholesale Price Index for Industrial Commodities,[41] and the labor cost adjusted by the appropriate index from the Standard Industrial Classification of SIC 372- series for nonelectrical items or SIC 36-- for electrical items.[39] The period of review should balance the cost of review against the potential value of an update, but in any case should be agreed beforehand (Section 4.6).

2. An exclusive contract with security of tenure for three to five years. The period of agreement could also be specified in terms of flight hours, cycles or flights. A long contract period is required to make modifications attractive. The contract should be renegotiated when 25% of the term remains to allow the vendor to properly plan modifications.

3. All money owed by the operator at termination. The vendor then refunds within a specified period (≤ 90 days) an agreed percentage, based on the ratio of overhaul to total maintenance costs, of that paid since the item was new or last overhauled. The operator must notify the vendor of the time on the items at the time of sale and the above would still apply.

4. A semi-regulated flow of work because the airline can be required to notify the vendor of an approaching overhaul a specified period of time before the overhaul is required. Quarterly flow limits can be placed on overhauls, but not, of course, on rectifications. If the overhaul flow limits are exceeded, the vendor is given turnaround-time relief or relief from providing a spare (if an exchange agreement is in effect) provided that it is not the vendor's fault, i.e., improper repair or overhaul.

The contract, besides providing for the items mentioned above, should do the following:

1. Hold neither vendor nor operator responsible for circumstances outside their control, but require reasonable efforts to negate them.

2. Prevent either party from assigning the agreement.

3. Allow the agreement to be terminated prior to expiration if one of the parties faces: bankruptcy, liquidation, consolidation of debts, or receivership.

4. Provide for lease-in components by adjusting the overhaul portion of the rate per hour (and/or cycle) cost by the reciprocal of the fraction of time remaining to overhaul, but keeping the rectification portion constant. Lease-outs are no problem if usage is similar or the contract is comprehensive enough to compensate for use in another locale or for varying cycles per flight-hour, etc.

5. Require the airline to pay for all modifications required to meet regulatory noise and pollution requirements enacted after the agreement, at a competitive rate.

6. Restrict airline maintenance on an item to that maintenance which could not reasonably be expected to result in expense to the vendor, e.g., measurements, consumables, and noncovered accessory replacements.

A contract based on the above has been found to result in:

1. A continuous mutual interest by airline and vendor in product performance. The vendor now does not want the product in his shop and performs preventive maintenance on items not involved in the current failure. He is motivated to pursue longer times-between-overhaul. And, if he is the manufacturer, he will be armed with the best engineering data to persuade the regulatory authority to allow increased limits.

Figure 4-3 shows the actual experience of British Caledonian Airways with items on BAC 1-11s and VC-10s. Marked improvement is shown in both MTBFs and TBOs.

2. Elimination of the need for invoices, a minimum

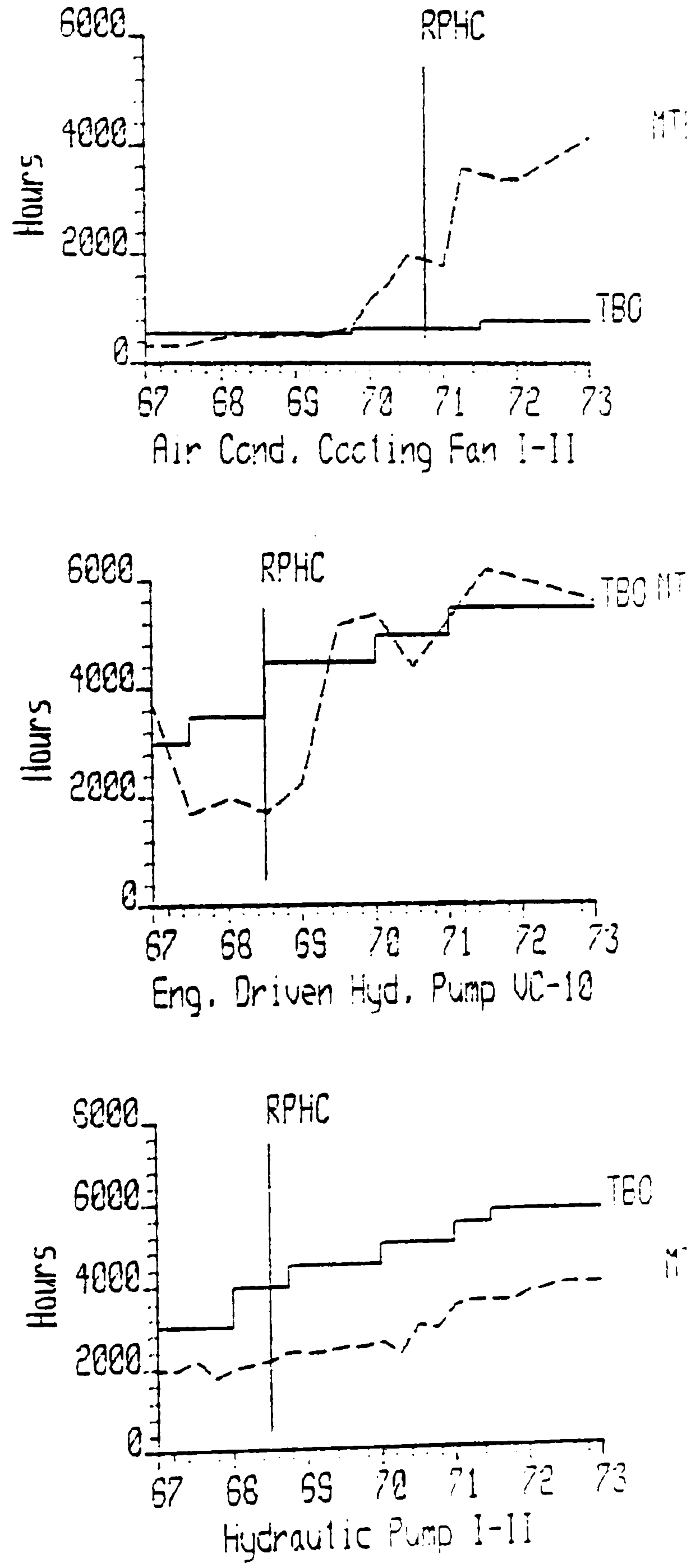


FIGURE 4-3
EFFECTS OF RPHC

number of contentious situations, accurate budgeting, and reduced capital outlay and administrative burden.

3. Improvement over the "exchange" type contract. It is cheaper for the airline because the vendor no longer makes more money with more failures, and he is motivated to do modifications. And, the vendor is now assured a guaranteed income for a set period.

The choice of vendor will probably be the result of the airline's experience and the vendor's willingness to participate. In general, the manufacturer has been found cheaper and more effective in increasing TBOs. Independent overhaulers generally give quicker turnarounds, better spares support, and are better at salvage than the manufacturer, an item that becomes increasingly important for those components whose parts or raw material prices are rapidly increasing.

The negotiation of a contract should take into account the time and cost of transit and overhaul and the size of the airline. An eight-aircraft third-level airline should be large enough to get an excellent agreement. The rate per hour offered can also be used for in-house budgetary discipline, e.g., maintenance and management negotiate whether maintenance does the repair or the airline sends it out. This is a decision that should be taken in light of the cost of maintenance and equipment investment or divestment. In renegotiating the contract, the airline knows the modification status, approximate cost, and the vendor's approximate investment to increase the MTBF, MTBMA, and TBO. Hence, the airline will know if the new rate-per-hour, cycle or flight is reasonable.

4.5.1 Rate Per Hour Contracts for Engines

The assumptions and calculations for the net-present-value of a Rate Per Hour Contract for engines, from the results of the simulation program (Figure 4-2) and the computed service level (Table 4-8) are given in Table 4-10. It is evident that the final cost to the airline is a strong function of the assumptions. The most important being the tooling saving available to the airline. Previous policies may greatly influence the saving available. And, it is difficult to imagine three identical airlines that could render exactly the results obtained.

The contribution term is also variable. Engine manufacturers (4 respondents) stated that contribution ranged from 30% to 45% after the discount to the airline, but that firms having federal contracts are required by the terms of the federal contract to spread some of their fixed costs over subsequent contracts.

The assumption was made that under a RPHC with the manufacturer the additional or reduced contribution would be negotiable on the basis of reduced or additional spares required with a RPHC. With the airlines obtaining a RPHC without an exchange agreement, three extra engines would be required. Two cases of nonpooling of spares were considered, returning the contribution resulted in a NPV of -$75686 per airline, and retaining the contribution resulted in a NPV of -$29069 per airline. Therefore, neither situation was financially beneficial.

TABLE 4-10

RATE PER HOUR CONTRACTS FOR ENGINES

ASSUMPTIONS

Project Life	: 5 Years
Capital Costs	: 13% for Airline and Vendor
Depreciation	: Sum-of-the-Years'-Digits, 7 Years for Airline & Vendor
Investment Tax Credit (ITC)	: 10% for Airline & Vendor
Tool Savings	: $47930 Per Airline
Engine Shipping Cost	: $200 One-Way
Extra Shipments With RPHC	: 20 Return Trips Per Year Per Airlines
Repair Cost	: Identical for Airline & Vendor
Stockholding Costs	: 8% Per Year, for Airline & Vendor
Airlines Participating in RPHC	: 3, 20000 Hours Per Year Each
Contribution of Engine To Manufacturer's Overheads	: 45%

PRECALCULATIONS

Cumulative Present Value Factor, 5 Years @ 13%	: 3.517
Shipment Costs Per Year (3 X 2 X 20 X $200)	: 24000

From Engine Simulation Graphs (rounded to integer values):

3 Airlines, No RPHCs (Curve 1)	: 15
3 Airlines, RPHCs, No Exchange (Curve 2)	: 18
3 Airlines, RPHCs, Exchange Agreement	
Held by Vendor (Curve 3)	: 9
Held by Airlines (Curve 4)	:+ 3
	--
Total Engines Held	: 12

NET-PRESENT-VALUE OF RPHC WITHOUT EXCHANGE AGREEMENT -- CONTRIBUTION RETURNED

ENGINE COST

Engine NPV	95481	
Extra Engines (18-15)	X 3	

PV of Engines		(286443)

SHIPPING COST

Shipping Cost Per Year	24000	
CUM PV Factor	X 3.517	

PV of Shipping		(84408)

TABLE 4-10
(cont'd)

RATE PER HOUR CONTRACTS FOR ENGINES

TOOL COST			
Tool Cost	47930		
Number of Airlines	X 3		

PV of Tool Savings		+143790	

NET-PRESENT-VALUE OF RPHC TO AIRLINES (3)			(227058)
NET-PRESENT-VALUE OF RPHC TO EACH AIRLINE			(75686)
NET-PRESENT-VALUE OF RPHC WITHOUT EXCHANGE AGREEMENT -- CONTRIBUTION RETAINED			
NPV of RPHC to Airlines (3) w/o Exchg		(227058)	
PV OF CONTRIBUTION			
Engine Cost	103594		
Contribution Rate	X 0.45		

Contribution Per Engine	46617		
Number of Engines	X 3		

PV of Contribution		+139851	

NET-PRESENT-VALUE OF RPHC TO AIRLINES (3)			(87207)
NET-PRESENT-VALUE OF RPHC TO EACH AIRLINE			(29069)
NET-PRESENT-VALUE OF RPHC WITH EXCHANGE AGREEMENT -- CONTRIBUTION RETAINED			
ENGINE SAVINGS			
Engine NPV	95481		
Engines Saved (15-12)	X 3		

PV of Engines Saved		286443	
Tool Savings		143790	
Shipping Cost		+(84408)	

NET-PRESENT-VALUE OF RPHC TO AIRLINES (3)			345825
NET-PRESENT-VALUE OF RPHC TO EACH AIRLINE			115275

TABLE 4-10
(concl'd)

RATE PER HOUR CONTRACTS FOR ENGINES

NET-PRESENT-VALUE OF RPHC WITH EXCHANGE AGREEMENT -- CONTRIBUTION RETURNED

NPV of RPHC to Airlines (3) w/Exchange		345825	
PV OF CONTRIBUTION			
Engine Cost	103594		
Engines Saved	X 3		

Saved Engine Cost	310782		
Contribution Rate	X 0.45		

PV of Contribution		+(139852)	

NET-PRESENT-VALUE OF RPHC TO AIRLINES (3)			205973
NET-PRESENT-VALUE TO EACH AIRLINE			68658

Spares could be pooled. If the spares pool were held by the manufacturer, the return of the contribution would be negotiable. If the spares pool were held by an overhaul agency, the airlines could claim the contribution. Both cases are shown, the first where the contribution of the engines saved is claimed by the airlines and the second where it is assumed returned to the manufacturer. The first case increases the stock value of the airline by $115275. The second case, returning the contribution, increases the stock value of the airline by $68658.

4.5.2 Rate Per Hour Contracts for Avionics

In the third-level industry, approximately one-half of the airlines maintain their own avionics shops while the other half normally have a contractual arrangement. This situation was investigated under the usual assumptions to determine the net-present-value of an operation with an avionics shop (-$190423) and without an avionics shop (-$238259) (Table 4-11). The results were then converted into the number of hours per year an airline must fly (15228 hours) before it can justify an avionics shop (Table 4-12). The maximum rate per hour cost if the airline is too small to operate its own shop, both with ($2.0661 + ($1608/Annual Flight Hours)) and without ($2.0661) an exchange agreement, and the rate per hour cost if the airline were large enough to operate its own shop (($22960/Annual Flight Hours) + $0.4774), in this instance an exchange agreement was assumed (Table 4-13).

The most important assumption, besides the type of avionics (Collins Pro-Line) and shop equipment (Appendix H), is that there are no economies of scale in labor or parts available to the operator as airline size changes from 10000 to 35000 hours per year. The avionics shops (11 respondents) and manufacturers (4 respondents) were unable to give any general economies of scale; economies of scale depend on individual circumstances.

4.6 Reliability Guarantees

The airline would like a high degree of confidence in its cost of utilization of an item. Besides the purchase price and the cost of consumables, both of which may be determined before purchase, the cost of utilization depends on the maintenance required. The cost of maintenance is relatively indeterminate in the early stages of development. This, plus competition, has prompted the airlines to require, and the manufacturers to offer, reliability guarantees. Reliability is often expected to increase with time as experience with an item increases. The uncertainty of the failure rate and the length of the guarantee necessitate periodic reviews until design maturity is reached. The length of the review period can be of significance when the time value of money and inflation are taken into account. It is essential to develop a method to take these factors into account in a nonpunitive fashion for both the airline and the manufacturer.

The components of maintenance cost can normally be expressed in terms of cost per flight-hour, for some items a cost per flight-cycle may be

TABLE 4-11

EVALUATION OF AVIONICS SHOP

ASSUMPTIONS

Project Life	:	10 Years
Cost of Capital	:	13%
Depreciation	:	Sum-of-the-Years'-Digits, 7 Years
Residual	:	10% Electronics & Shop
Resale Value	:	20% Electronic & Office 50% Shop
Investment Tax Credit (ITC)	:	10%
Tax Rate	:	52%
Capital Gains Tax Rate	:	50%
Stockholding Costs Per Year	:	8%
Airline Hours Per Year	:	20000
Spare Parts	:	$0.4641 Per Flight Hour
Contract Repair Costs	:	$1.8465 Per Flight Hour
Shipping Cost	:	$25 Per Item
Failures Per year	:	207
Land Rental	:	$432 Per Year
Shop Cost New (300 Sq. Ft. @ $20/Sq. Ft.)	:	$6000
Technician's Salary	:	$20000 Per Year
Parts Cost With Own Shop	:	75% of Contracted Cost
Outside Contract Work With Own Shop	:	None Assumed
Savings In Spare Units With Own Shop	:	$9100 (One VIR-30A, One 332C-10)
Spare Parts Inventory With Own Shop	:	$7350 (6 Months of Spares)

PRECALCULATIONS

Cumulative Present Value Factor, 10 Years @ 13%	:	5.426
Present Value Factor, 10 Years @ 13%	:	0.2946
Net-Present-Value of Depreciation, @ 13%	:	0.7081
Taxable Capital Gains on Shop (50%-10%)	:	40%
Taxable Capital Gain Equipment & Spares (20%-10%)	:	10%

CALCULATIONS

COST WITH SHOP

EQUIPMENT

Electronic Equipment	58469	
Office Equipment	+ 2300	

Equipment Cost		60769
Labor	20000	
Cum PV Factor	X 5.426	

PV of Labor		108520

TABLE 4-11
(cont'd)

EVALUATION OF AVIONICS SHOP

SPARE PARTS			
List Cost Per Hour	0.4641		
Net Cost Factor	X 0.75		

Cost Per Hour	0.3480		
Hours Per year	X 20000		

Cost Per Year	6960		
CUM PV Factor	X 5.426		

PV of Spare Parts		37765	
STOCK			
Stock Cost		7350	
Stock Costs	7350		
Stockholding Rate	X 0.08		

Stockholding Costs	588		
CUM PV Factor	X 5.426		

PV of Stockholding		3190	
SHOP AND LAND			
Shop Cost		6000	
Land Rental	432		
CUM PV Factor	X 5.426		

PV of Land Rental		+ 2344	

PV of Shop Cost			(225938)

TABLE 4-11
(cont'd)

EVALUATION OF AVIONICS SHOP

TAX CREDITS

INVESTMENT TAX CREDIT (ITC)

Equipment	60769	
Stock	7350	
Shop	+ 6000	

Total Cost	74119	
ITC Rate	X 0.10	

Investment Tax Credit		7412

DEPRECIATION

Total Cost	74119	
Depreciable Fraction	X 0.90	

Depreciable Amount	66707	
PV Factor	X 0.7081	

PV of Deprec. Before Tax	47234	
Tax Rate	X 0.52	

Depreciation After Tax		24562

RESIDUAL VALUE

Total Cost	74119	
Residual	X 0.10	

Residual Value	7412	
PV Factor	X 0.2946	

PV of Residual		2184

CAPITAL GAINS

Equipment	60769
Stock	+ 7350

Total	68119
Subject to Tax	X 0.10

TABLE 4-11
(cont'd)

EVALUATION OF AVIONICS SHOP

CAPITAL GAINS (cont'd)				
Taxable Amount		6812		
Shop	6000			
Subject to Tax	X 0.40			

Taxable Amount		+ 2400		

Total Taxable Amount		9212		
Retention Rate		X 0.50		

After Tax Savings		4606		
PV Factor		X 0.2946		

Gain Less Residual			+ 1357	

PV of Tax Credits				+ 35515

NET-PRESENT-VALUE OF SHOP				(190423)

COST WITHOUT SHOP

REPAIRS			
Repair Costs ($/Hour)	1.8564		
Hours Per Year	X 20000		

Repair Costs Per Year	37128		
CUM PV Factor	X 5.426		

PV of Repair Costs		201456	
SHIPPING			
Shipping Cost	25		
Shipments Per Year	X 207		

Annual Shipping Costs	5175		
CUM PV Factor	X 5.426		

PV of Shipping		28080	

TABLE 4-11
(concl'd)

EVALUATION OF AVIONICS SHOP

STOCK			
Stock Cost		9100	
Stock Cost	9100		
Stockholding Rate	X 0.08		
Stockholding Cost	728		
CUM PV Factor	X 5.426		
PV of Stock Storage		3950	
Tax Credits (As Computed Above)		+ 4327	
PV of Cost Without Shop			(242586)
Stock Tax Credits (As Above)			+ 4327
NET-PRESENT-VALUE WITHOUT SHOP			(238259)

TABLE 4-12

ANNUAL FLIGHT TIME REQUIRED TO JUSTIFY AVIONICS SHOP

COST PER HOUR		
Net-Present-Value Without Shop	238259	
PV Factor	÷5.426	

Annual Cost	43911	
Hours Per Year	÷20000	

COST PER HOUR WITHOUT SHOP		\$2.1955
COST PER YEAR LESS SPARES		
Net-Present-Value of Shop	190423	
PV of Spare Parts	- 37765	

Net-Present-Value Less Spares	152658	
Cum PV Factor	÷5.426	

Annual Cost Less Spares		28135
LABOR COST PER HOUR WITHOUT SHOP		
Cost Per Hour Without Shop	2.1955	
Less Spares Cost Per Hour W/Shop	- 0.3480	

Labor Cost Per Hour Without Shop		÷1.8475

ANNUAL FLIGHT TIME REQUIRED TO JUSTIFY AVIONICS SHOP (HOURS)		15228

TABLE 4-13

AVIONICS RATE PER HOUR CONTRACTS

LESS THAN 15228 ANNUAL FLIGHT TIME WITHOUT EXCHANGE AGREEMENT

Cost Per Hour	2.1955	
Less One-Way Shipping	- 0.1294	

REQUIRED RATE PER HOUR CONTRACT COST		$2.0661

LESS THAN 15228 ANNUAL FLIGHT TIME WITH EXCHANGE AGREEMENT

Stock Costs	9100	
Stock Holding Costs	3950	
Tax Credits	+ (4327)	

Net Stock Cost	8723	
Cum PV Factor	÷5.426	

Annual Stock Cost		$1608

REQUIRED RATE PER HOUR CONTRACT COST $2.0661 + ($1608/(Flight Time))

MORE THAN 15228 ANNUAL FLIGHT TIME

SPARES AND SHIPPING SAVINGS

Cost of Shop Less Spares	28135	
Annual Shipping Costs	- 5175	

Annual Shop Costs Less Spares and Shipping		$22960

FIXED PER HOUR COSTS

Spares Cost Per Flight Hour		$0.3480
Annual Shipping Costs	5175	
Hours Per Year	÷20000	

Shipping Costs Per Hour	0.2588	
Trips Per Shipment	÷2	

One-Way Shipping Cost Per Hour		$0.1294

Fixed Per Hour Costs		$0.4774

REQUIRED RATE PER HOUR CONTRACT COST ($22960/(Flight Time)) + $0.4774 more meaningful, and still others may require a combination of both. If the guarantee is expressed in terms of current dollars in the year of the contract, the remuneration per unit of utilization required in any year, t, taking inflation into account is given by:

$$C(t) = \left(\sum_{m=1}^{M} AC(t)_m - \sum_{n=1}^{N} GC(t)_n \left[\frac{I(t)_n}{I(1)_n} \right] \right) \div U(t)$$

where

$C(t)$ is guarantee shortfall per unit of utilization in year t in year-t dollars,

$AC(t)_m$ is the actual cost of element m in year t,

$GC(t)_n$ is the guaranteed cost of cost element n in year t,

$I(1)_n$ is the appropriate price index of element n in year 1, the year of the contract,

$I(t)_n$ is the appropriate price index of element n in year t

$U(t)$ is the units of utilization in year t,

m's are the expense parameters allowed, and

n's are the guaranteed parameters.

Normally M equals N and m equals n. AC(t) and GC(t) are functions of other maintenance parameters, e.g., MTBF, MTTR, MCTR, MTBMA, spares level.

The guarantee payment due in year t is given by:

$$GP(t) = C(t)\, U(t)$$

where

$GP(t)$ is the guarantee payment in year t, and

$C(t)$ and $U(t)$ are as defined above.

For two bases of utilization (hours and cycles) we would get a GP(t) that is the sum of two component GP(t)s.

If the time value of money is taken into account the payment received is given by:

$$P = \sum_{t=1}^{T} \left((GP(t) \prod_{q=1}^{t} (1 + DR(q)/100) \right)$$

where

P is the payment due,

T is the number of years since the contract date or the last payment, and

q varies from the present back to the year t.

DR(q) is the discount rate in year q in percent and is given by the larger of:

$$DR(q) = \frac{(GP(q) + I(q))\ 100}{L(q) - CL(q)}$$

where

I(q) is the income in year q before tax and interest,

L(q) is the total liability in year q,

CL(q) is the current liability in year q, and

GP(q) is as defined above.

or

$$DR(q) = \frac{IC(q)\ 100}{D(q)}$$

where

IC(q) is the interest charged in year q, and

D(q) the total debt in year q.

Thus, if the average-weighted cost of capital of the airline is less than its cost of debt, it recovers at its cost of debt. This guarantees that the airline, when paid, will not have suffered as an investment from a shortfall in the reliability guarantee or postponement of the payment (unless, of course, it goes bankrupt because of the delayed payment).

It will be seen at this point that the contract can be written with three different restrictions that will influence the guarantee offered and the guarantor's attitude towards modifications to improve the basic parameters, e.g., MTBF, MTTR, MCTR, MTBMA.

1. If GP(t) is restricted to positive values the guarantor cannot recover a shortfall in year t in future years. Hence, he will be most restrictive in his commitments.

2. If P is restricted to positive values this enables the guarantor to recoup losses of the past by improved performance in the future, but prohibits him from realizing greater future income from modifications.

3. If P is allowed to go negative, the guarantor stands to make a profit with negative values. If he is allowed this bonus he will be motivated to provide the best possible performance consistent with the period of guarantee and investment required, and he will give the most optimistic guarantee. This sets a minimum cost for utilization of the item by the airline. However, if only an agreed fraction of a resulting negative GP(t) is returned, both the guarantor and airline could share the gains.

Obviously, it will always benefit the guarantor to give the minimum acceptable guarantee under each of the three restrictions.

5. SCHEDULING AND ROUTE SELECTION

5.1 Introduction

This section develops the route network, schedules, pricing policy, and the most-likely estimates of route, station, and airline statistics for the time period from 1978 to 1987. This is an iterative process, and only the last iteration is shown.

It is necessary to analyze the interaction of demand, cost, and price to develop a schedule which maximizes systemwide contribution (after-ticket-tax revenues minus variable costs). The policy of maximizing contribution in the short term is equivalent to maximizing stockholder wealth or return-on-investment (ROI) in the long term.[64] Hence, the decision to add or delete a station or route is based on the contribution of that station or route.

5.1.1 Schedule Requirements

In deriving a schedule, it is first necessary to determine the requirements of the interested parties:[65]

1. The passenger wants:

   a. Low fares and a maximum of amenities

   b. A seat available at the time he wants to go regardless of the time of day, day of the week, month, or year--the inability of the airline to provide a seat adversely affects passenger good will, long-term promotion, community interest, and public air transport policy

   c. The shortest possible time to destination with the fewest possible stops

   d. Consistent, easy-to-read, easily remembered flight schedules

   e. Complete itineraries available from an airline or travel agent[66]

   f. Tickets accepted by all airlines to whom they are presented[66]

   g. Baggage checked through to the final destination[66]

2. The shipper wants:

   a. As many flights as possible in the evening so he can ship the products of the day

   b. Through flights to eliminate possible shipment and paperwork misplacement

3. The community wants:

   a. A low-profile service--airlines are big business, high technology and visible; everything distasteful to the modern reaction towards humanism

   b. All flights to stop--they detest vapor trails that are indicative of nonstop flights to other cities

4. The airport authority wants:

   a. No peaking of passengers or aircraft operations either by the hour of the day, the day of the week, or the season of the year

   b. Aircraft that can use, but not abuse, current runways

   c. Quiet aircraft to satisfy the surrounding community's objections to noise

   d. Adequate seat capacity so that standby passengers do not fill the waiting rooms

   e. Standardized aircraft so handling facilities can be standardized

5. The government wants:

   a. More capacity and frequency than other the countries' flag carriers on international routes

   b. Nonstop service from the capital to the constituencies

6. The post office wants arrival and departure times to coincide with their pick-up and delivery times

7. The hotel wants arrival and departure times around their check-out times

8. The travel agent wants all flights departing at the same time year-round under the same flight number

9. Teh other airlines want the carrier to have poor schedules and what schedules it does have to connect with their own flights

10. The airline wants:

    a. Maximum return-on-investment

    b. Good utilization of resources

    c. The best compromise for all interested parties except the competition

Additional important travel demand considerations for short-haul airlines are given in Table 5-1. The rest of this chapter is

TABLE 5-1

IMPORTANT TRAVEL FACTORS IN SHORT-HAUL

The product of an airline is a time savings; no time savings, no passengers.

The elasticity of quality of service and price are highest in short-haul because suitable substitute modes are available.

Delays are the major cause of airline dissatisfaction, and they erode the perceived time savings fastest in short-haul.

The shorter the stage length, the less an airline can afford to turn away customers--the delay for the next flight may become intolerable.

The shorter the stage length, the higher the required frequency and the smaller the required aircraft. Frequency works better than size to stimulate travel, but unit production costs are proportional to aircraft size to the -0.33 power.[73]

Passengers making single-day trips value time and frequency more than those making multi-day trips.

Most short-haul markets are more quality-of-service elastic than price elastic. Therefore, frequency and reliability will do more than price to stimulate traffic.

The advantages of air are proportional to distance because the time savings of air grows faster than the monetary savings of surface transport.

High-income travelers value time more than low-income travelers. A business traveler, because his value to the business exceeds his salary, has a greater perceived income (value) on a business trip than on a personal one.

concerned with developing the best possible compromises, particularly from the point of view of the airline.

5.1.2 Route System

The proposed route system is shown in Figure 5-1. Despite appearances this is a pure hub-and-spoke route system with two hubs, Portland and Medford. The third-level aircraft going south from Portland to Medford and back do not carry any traffic between Portland and Medford. This is assumed done by a certificated carrier(s), Section 1.6.1.

Eugene, Oregon's second largest city, was not offered service. A third-level airline could not compete between Eugene and Portland or Eugene and Medford with certificated service which, with subsidy, could operate at a profit while generating revenue below the break-even point. Landing at Eugene would generate little intra-Oregon traffic for aircraft on routes through Corvallis-Albany, Roseburg, or Salem, but connecting passengers could connect with jet service at Eugene rather than continuing on the third-level airline to Portland or Medford. Newport (Figure 3-1) did not produce a positive contribution and was dropped. The circumstances under which Newport could be served will be discussed later, Section 5.4.8.

An initial assumption, Section 1.6.1, was that third-level aircraft going to Medford would be meeting a certificated carrier that had arrived from San Francisco with passengers for the Oregon cities. And, that a certificated carrier would be collecting the arriving connecting Oregon passengers and taking them to San Francisco. The certificated aircraft could be one in the same, or one could be coming south from Portland and Eugene to San Francisco and the other coming north from San Francisco and continuing on to Eugene and Portland, with the aircraft crossing at Medford.

5.2 Schedule Timing

In order to determine an optimum schedule, it was first necessary to determine the time for an aircraft to depart Portland to Medford via a city in Oregon, return to Portland via a city in Oregon, and be serviced and ready for another departure in Portland. The constraints are the following:

1. Block times are estimated as suggested in Section 3.2.4.6.

2. Turnaround time, which must include refueling, is a minimum of 12 minutes and averages 14 minutes at all stations; except Portland and Medford where it is a minimum of 30 minutes and averages 35 minutes.

3. Because the route through Klamath Falls is the longest and the route through Salem the shortest, the aircraft going south through Klamath Falls returned north through Salem and vice versa. Based on second longest and second shortest routes, the same changeover is made for routes between Redmond-Bend and Albany-Corvallis. This enabled all aircraft to have turnaround times near the mean.

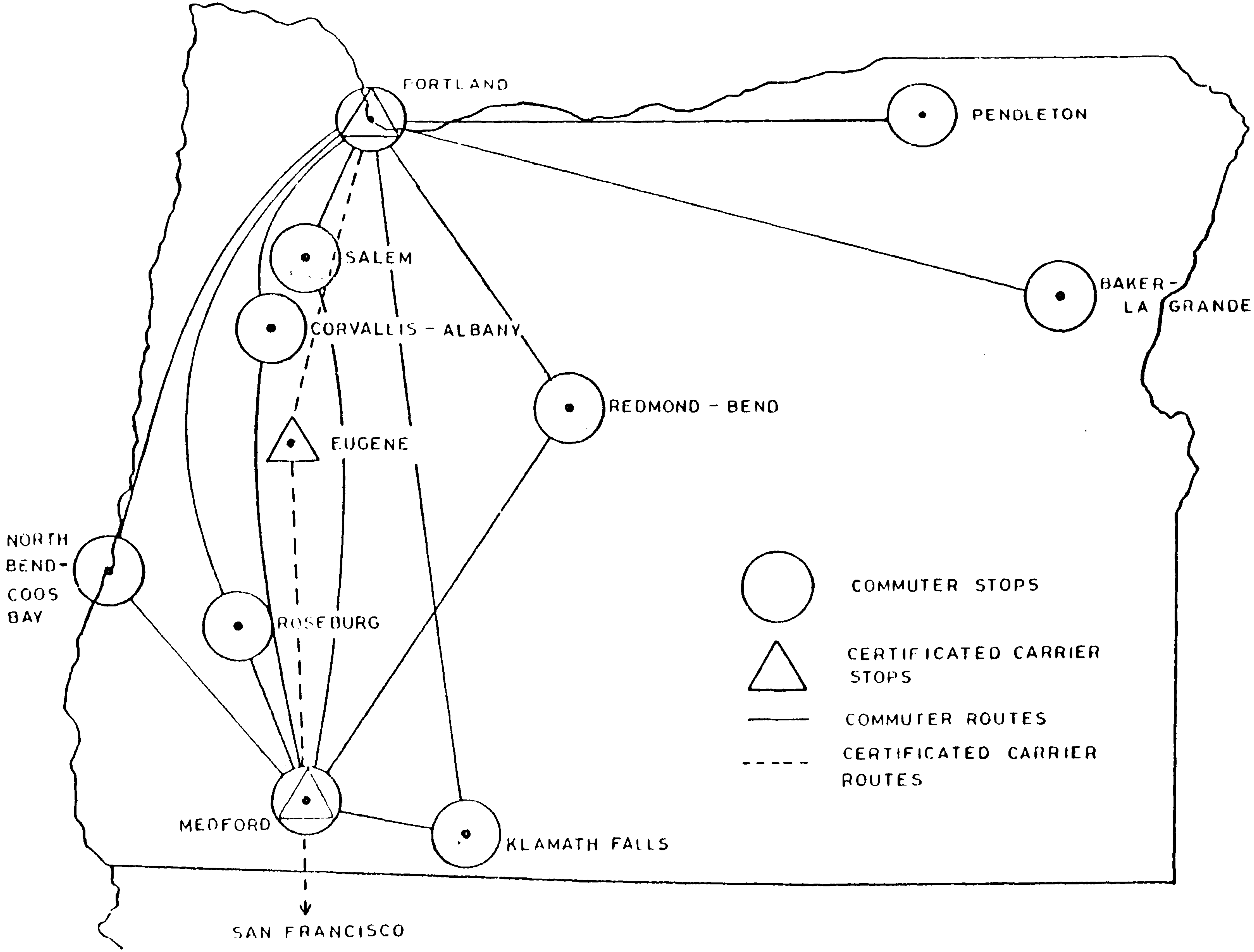


FIGURE 5-1
PROPOSED OREGON ROUTE SYSTEM

4. Aircraft are scheduled to arrive and depart Portland and Medford at two-minute intervals. This is equivalent to Medford's IFR capacity; Medford has no radar.[44]

5. The certificated carrier aircraft landed last and departed first at Medford with a 16-minute turnaround.

Based on these assumptions, a complete circuit takes four and one-half hours. The assumptions above are conservative; third-levels normally only account for mean winds (Section 3.2.4.3) and typically schedule turnarounds of from six to twelve minutes in length.

Given the time to complete a circuit, optimum timing was determined to be a function of the frequency factor component of the intra-Oregon travel demand model, Section 2.5.

A mean perceived time savings with an ideal departure, ΔT, was found by taking a weighted average of:

$$\overline{\Delta T} = \frac{\sum_{n=1}^{8} PIM_n^{K4}\ DP^{K5}\ \Delta T_n}{\sum_{n=1}^{8} PIM_n^{K4}\ DP^{K5}}$$

where

$\overline{\Delta T}$ is the weighted mean perceived time savings with an ideal departure,

ΔT_n is the perceived time savings with an ideal departure at station n,

n is the station considered, Portland or Medford and Corvallis-Albany, Klamath Falls, North Bend-Coos Bay, Redmond-Bend, Roseburg, or Salem, and

the other coefficients are as defined in Section 2.5.

This value was then used in the persistence of demand function to compute the frequency factor. The local demand profile was modified by a factor:

$$\overline{M}(t)^{3.59346}$$

where

$\overline{M}(t)$ is the weighted mean meteorological completion factor on arrival. It is the fraction of time that weather is at or above landing minimums, and it is a function of the time of day, t.

It is defined by:

$$\overline{M}(t) = \frac{\sum_{n=1}^{N} \Delta T_n^{K2}\ PIM_n^{K4}\ DP^{K5}\ M(t)_n}{\sum_{n=1}^{N} \Delta T_n^{K2}\ PIM_n^{K4}\ DP^{K5}}$$

where

$M(t)_n$ is the meteorological completion factor for an aircraft arriving at station n at time t. M(t) is found from the "U. S. Naval Service World-Wide Airfield Summaries"[47] which provides eight data points at three-hour intervals throughout the day. M(t) is spline-fit at 6-minute intervals (0.1-hour) to (1.-(PT/100)), where PT is the percentage of time the airfield has less than a 300-foot ceiling or 1 statute mile of visibility.

N is one for inbound flights to Medford or Portland, and six for outbound flights to Corvallis-Albany, Klamath Falls, North Bend-Coos Bay, Redmond-Bend, Roseburg, and Salem.

The other coefficients are defined above or in Section 2.5.

$\overline{M}(t)$ is raised to the 3.59346 power because this is the exponent of reliability, K3, Section 2.5.

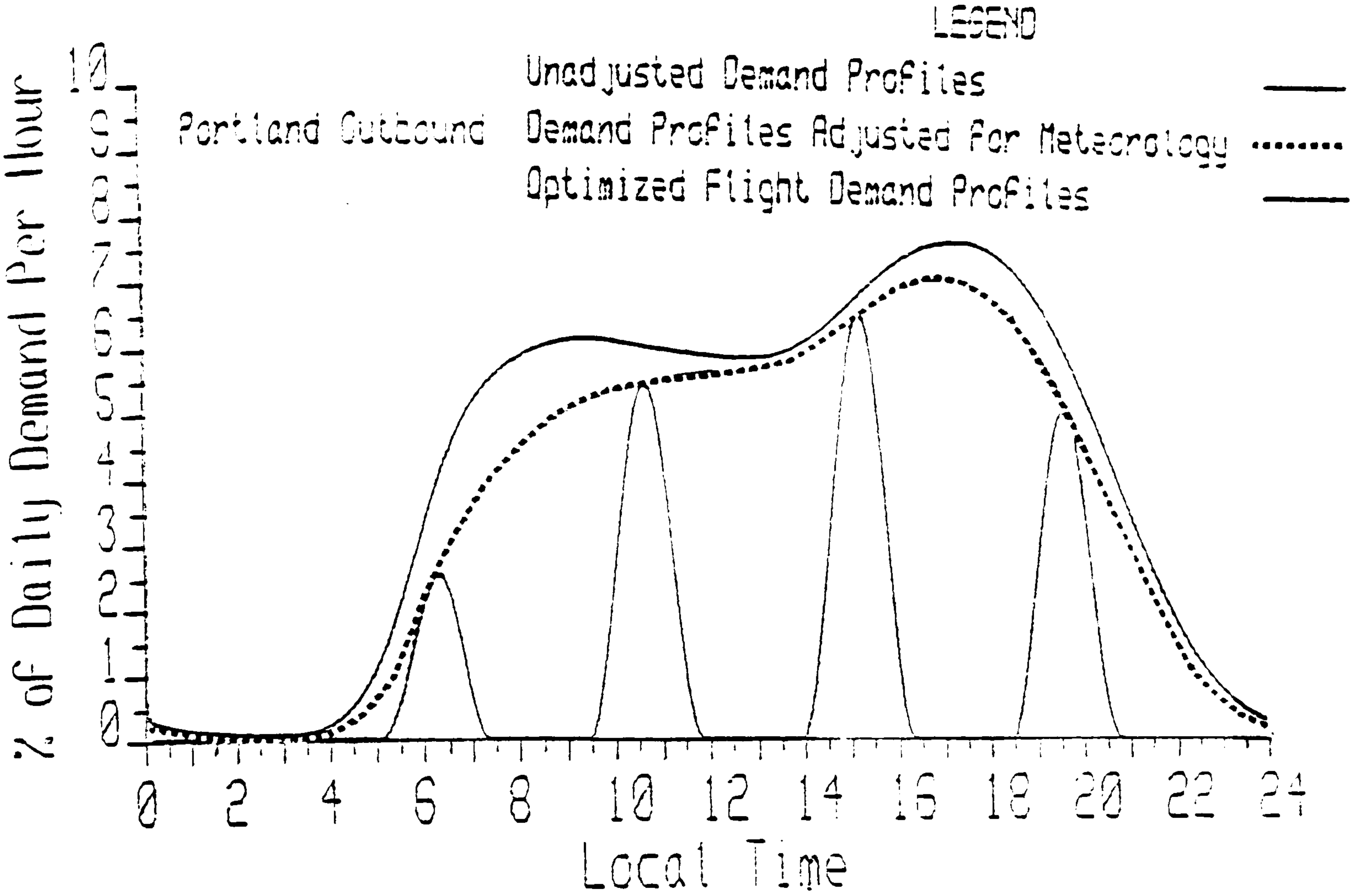
The results of these weightings when combined in the intra-Oregon travel demand model showed that intra-Oregon flights to Portland had potential, exclusive of price and reliability, 5.36 times as great as Medford.

Figures 5.2A, B, C, and D show the results of the optimization program. The top, solid curve is the intra-Oregon demand profile. The middle dashed-curve is the modification of demand for meteorology upon arrival. The lower curves are the meteorologically modified frequency factor components. The area under the lower curves, when multiplied by 5.36 for Portland and by 1.0 for Medford and added together, is the objective function to be maximized. The curves shown represent the maximum.

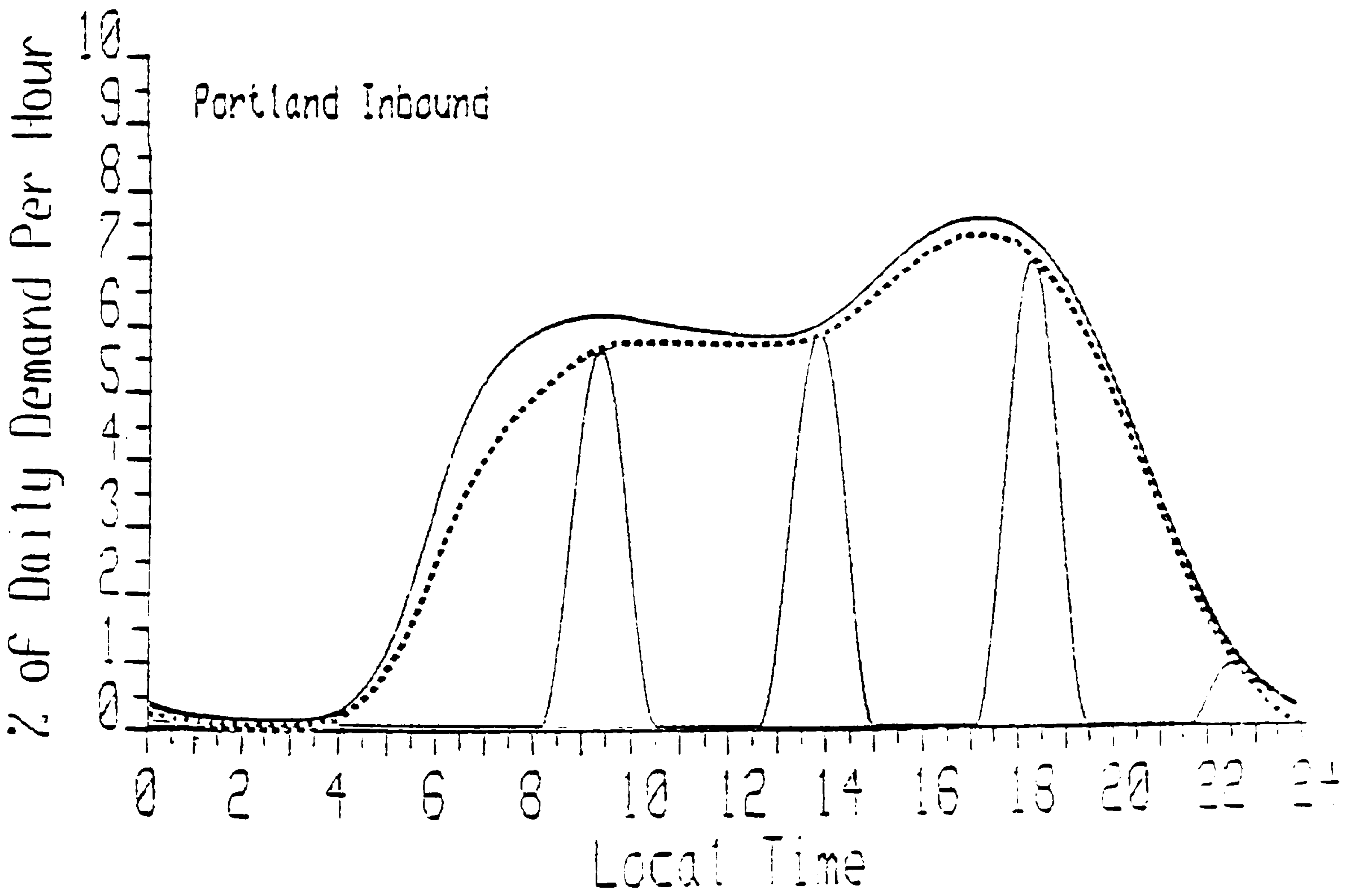
The curves show that arrivals at Medford are most restricted by meteorology (Figure 5.2D). The weighted arrivals at Corvallis-Albany, Klamath Falls, North Bend-Coos Bay, Redmond-Bend, Roseburg and Salem are second (Figures 5.2A and 5.2C; two cases, Medford Outbound and Portland Outbound). And, arrivals at Portland are the least meteorologically restricted (Figure 5.2B).

The program allowed the flights from Portland to originate at times exceeding four and one-half hours, but this was not productive.

Sensitivity analyses were run. Intra-Oregon demand was found to increase by 2% for each six minutes that the round trip time to

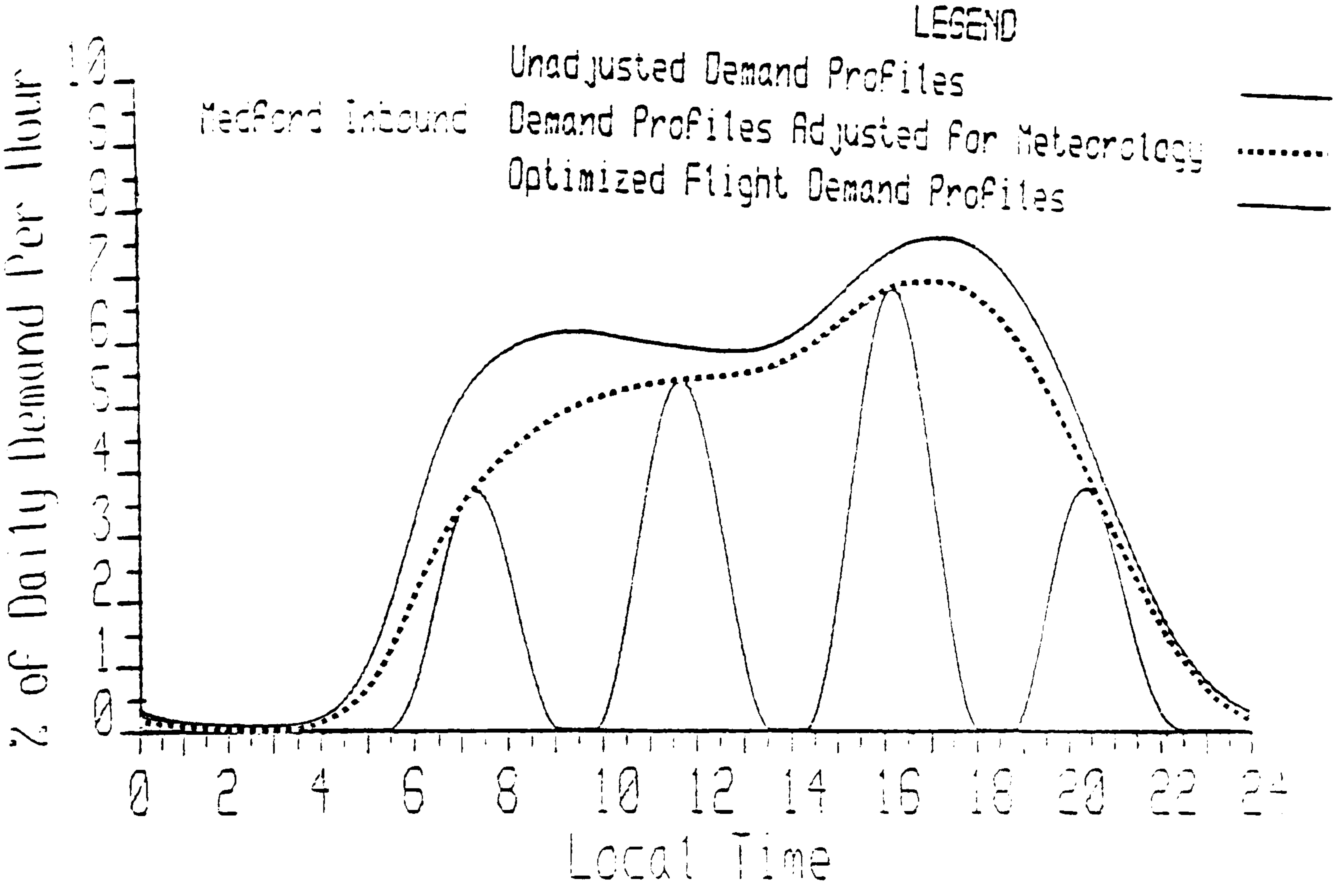


(A)

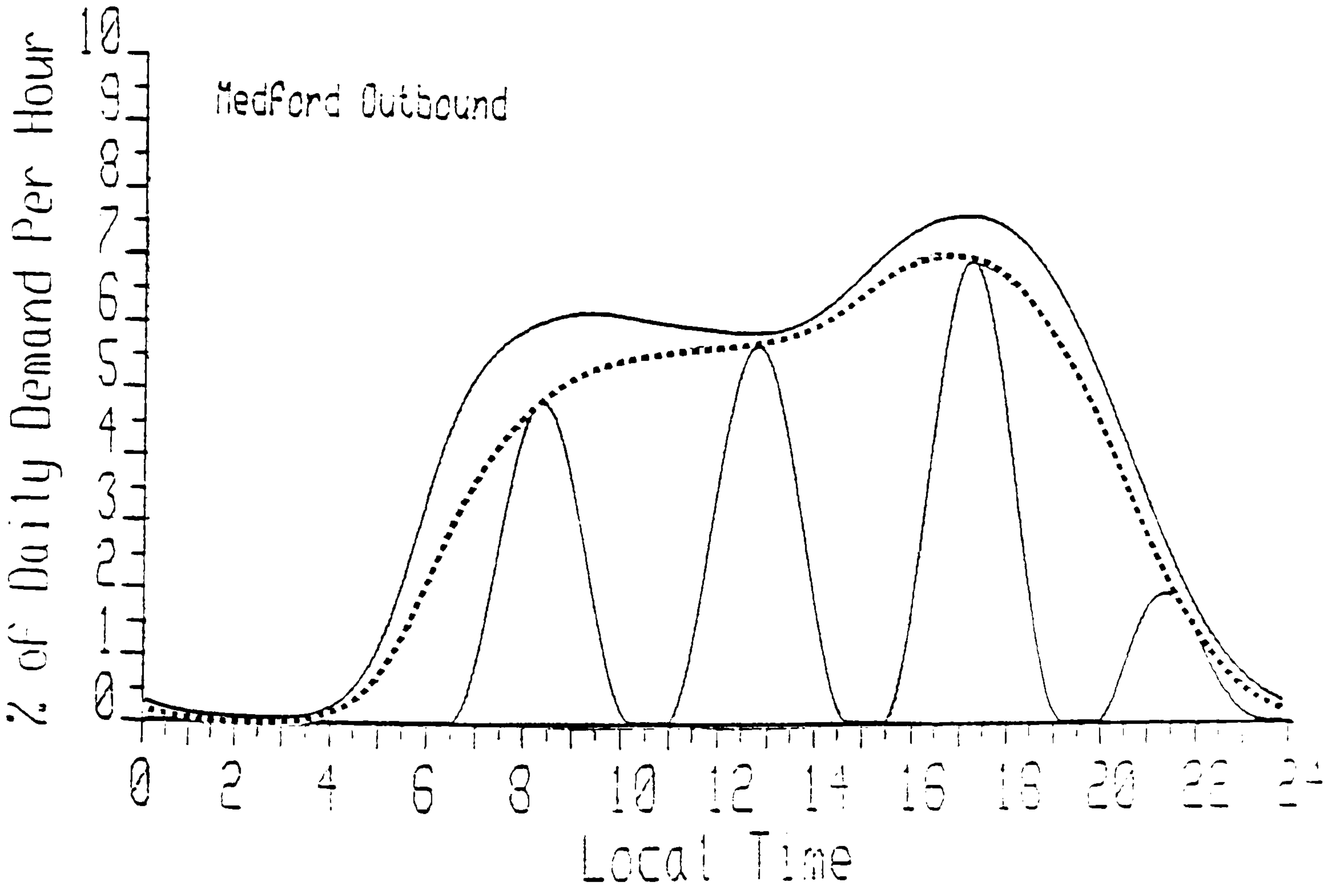


(B)

FIGURE 5-2
SCHEDULING FOR OPTIMUM DEMAND



(C)



(D)

FIGURE 5-2
SCHEDULING FOR OPTIMUM DEMAND
(CONTINUED)

Portland was reduced. At four hours, the demand had increased 10%. Each six-minute increment in round trip time resulted in the optimum schedule beginning six minutes later in the morning and, with four round trips, ending 18 minutes earlier in the evening. Even with round trip time shortened to four hours, there was no delay required between the flights from Portland to optimize the function. With little midday decrease in demand and the sloping shoulders of the demand profile squeezing the early morning and late evening flights, it is easy to see why this does not occur.

Connecting travel demand is not a function of frequency factor, but it is a function of frequency and constitutes over 60% of all boardings. The suitability of departure or arrival time varies throughout the day, but this does not affect demand in the connecting travel demand model. Air freight demand is a function of frequency, but it is assumed constant throughout the day. In practice, it peaks after 5 P.M. for departures and early the next morning for arrivals. If connecting travel and air freight demand had lead to demand being unserved because of excess demand for particular flights, further analysis would have been required.

If Medford is used as the airline domicile and maintenance base--trips begin in the morning and end in the evening at Medford--intra-Oregon traffic increases 10% because of the better timing of flights to Portland. This is rejected because the early connecting demand southbound can not be served.

Pendleton and Baker-La Grande were handled by the same program, but no averaging was required because only Pendleton or Baker-La Grande to/from Portland was considered. Optimization of routes to Pendleton was based on six round-trips a day and optimization of routes to Baker was based on four round-trips a day. In this instance, the flights did not make immediate turnarounds at Pendleton or Baker, but were spaced throughout the day because the time to complete a circuit (PDT-PDX-PDT or BKE-PDX-BKE) was sufficiently short to require it. Crews and aircraft were domiciled at Pendleton and Baker throughout the week and retained in Portland over the weekend for aircraft maintenance. The optimized schedules are shown in Table 5-2.

Schedules appropriate for a certificated carrier flying either San Francisco-Medford-San Francisco with one aircraft or San Francisco-Medford-Eugene-Portland-Eugene-Medford-San Francico with two aircraft are given in Table 5-3. The single aircraft schedule results in 2894 hours per year of utilization, and the two aircraft schedule in 5450 hours per year (2725 hours per aircraft) of utilization. The utilization is above the average of 3103 hours per year for a single aircraft or 2573 hours per year for two aircraft, based on the average block time (Section 3.2.4.8) for this type aircraft, DC-9-30 or B737-200.

5.3 Route Selection and Pricing

This section describes the philosophies of route selection and pricing and the inputs and features of the computer program that selected the routes and determined the fares. It is necessary to start with the pricing policy because it will partially determine the routes selected.

TABLE 5-2

OREGON AIRLINE SCHEDULE

BAKER-LA GRANDE	CORVALLIS-ALBANY	KLAMATH FALLS	NORTH BEND-COOS BAY
BKE-PDX 0730-0855[6,7]	PDX-CVO 0620-0656[7]	PDX-LMT 0610-0727[7]	PDX-OTH 0618-0714[7]
PDX-BKE 0930-1045	CVO-MFR 0712-0759[7]	LMT-MFR 0739-0808[7]	OTH-MFR 0727-0802[7]
BKE-PDX 1100-1225	MFR-CVO 0837-0924[7]	MFR-LMT 0831-0859[7]	MFR-OTH 0835-0912[7]
PDX-BKE 1300-1415	CVO-PDX 0938-1012[7]	LMT-PDX 0911-1027[7]	OTH-PDX 0925-1018[7]
BKE-PDX 1530-1655	PDX-CVO 1050-1126	PDX-LMT 1040-1157	PDX-OTH 1048-1134
PDX-BKE 1730-1845	CVO-MFR 1142-1229	LMT-MFR 1209-1238	OTH-MFR 1157-1232
BKE-PDX 1900-2025	MFR-CVO 1307-1354	MFR-LMT 1301-1329	MFR-OTH 1305-1342
PDX-BKE 2100-2215[5,6]	CVO-PDX 1408-1442	LMT-PDX 1341-1457	OTH-PDX 1355-1448
	PDX-CVO 1520-1556	PDX-LMT 1510-1627	PDX-OTH 1518-1614
	CVO-MFR 1612-1659	LMT-MFR 1639-1708	OTH-MFR 1627-1702
	MFR-CVO 1737-1824	MFR-LMT 1731-1759	MFR-OTH 1735-1812
	CVO-PDX 1838-1912	LMT-PDX 1811-1927	OTH-PDX 1825-1918
	PDX-CVO 1950-2026[6]	PDX-LMT 1940-2057[6]	PDX-OTH 1948-2034[6]
	CVO-MFR 2042-2129[6]	LMT-MFR 2109-2138[6]	OTH-MFR 2057-2132[6]
	MFR-CVO 2207-2254[6]	MFR-LMT 2201-2229[6]	MFR-OTH 2205-2242[6]
	CVO-PDX 2308-2342[6]	LMT-PDX 2241-2357[6]	OTH-PDX 2255-2348[6]

---

5 Except Friday.
6 Except Saturday.
7 Except Sunday.

TABLE 5-2
(concl'd)

OREGON AIRLINE SCHEDULE

PENDLETON	REDMOND-BEND	ROSEBURG	SALEM
PDT-PDX 0700-0810[6,7]	PDX-RDM 0616-0657[7]	PDX-RBG 0622-0716[7]	PDX-SLE 0624-0648[7]
PDX-PDT 0830-0930	RDM-MFR 0713-0805[7]	RBG-MFR 0730-0756[7]	SLE-MFR 0700-0753[7]
PDT-PDX 0945-1055	MFR-RDM 0833-0923[7]	MFR-RBG 0839-0905[7]	MFR-SLE 0841-0934[7]
PDX-PDT 1115-1215[6,7]	RDM-PDX 0935-1016[7]	RBG-PDX 0917-1010[7]	SLE-PDX 0947-1012[7]
PDT-PDX 1230-1340[6,7]	PDX-RDM 1046-1127	PDX-RBG 1052-1146	PDX-SLE 1054-1118
PDX-PDT 1400-1500	RDM-MFR 1143-1235	RBG-MFR 1200-1226	SLE-MFR 1130-1223
PDT-PDX 1515-1625	MFR-RDM 1303-1353	MFR-RBG 1309-1335	MFR-SLE 1311-1404
PDX-PDT 1645-1745	RDM-PDX 1405-1446	RBG-PDX 1347-1440	SLE-PDX 1417-1442
PDT-PDX 1800-1910	PDX-RDM 1516-1557	PDX-RBG 1522-1616	PDX-SLE 1524-1548
PDX-PDT 1930-2030	RDM-MFR 1613-1705	RBG-MFR 1630-1656	SLE-MFR 1600-1653
PDT-PDX 2045-2155	MFR-RDM 1733-1823	MFR-RBG 1739-1805	MFR-SLE 1741-1834
PDX-PDT 2215-2315[5,6]	RDM-PDX 1835-1916	RBG-PDX 1817-1910	SLE-PDX 1847-1912
	PDX-RDM 1946-2027[6]	PDX-RBG 1952-2046[6]	PDX-SLE 1954-2018[6]
	RDM-MFR 2043-2135[6]	RBG-MFR 2100-2126[6]	SLE-MFR 2030-2123[6]
	MFR-RDM 2203-2253[6]	MFR-RBG 2209-2235[6]	MFR-SLE 2211-2304[6]
	RDM-PDX 2305-2346[6]	RBG-PDX 2247-2340[6]	SLE-PDX 2317-2342[6]

5 Except Friday.
6 Except Saturday.
7 Except Sunday.

TABLE 5-3

CERTIFICATED CARRIER SCHEDULE

MEDFORD[1]

SFO-MFR	0706-0810[7]
MFR-SFO	0829-0932[7]
SFO-MFR	1136-1240
MFR-SFO	1259-1402
SFO-MFR	1606-1710
MFR-SFO	1729-1832
SFO-MFR	2036-2140[6]
MFR-SFO	2159-2302[6]

EUGENE[1,2]

PDX-EUG	0700-0729[7]
EUG-MFR	0742-0812[7]
MFR-EUG	0827-0856[7]
EUG-PDX	0909-0934[7]
PDX-EUG	1130-1159
EUG-MFR	1212-1232
MFR-EUG	1257-1326
EUG-PDX	1339-1404
PDX-EUG	1600-1629
EUG-MFR	1642-1712
MFR-EUG	1727-1756
EUG-PDX	1809-1834
PDX-EUG	2030-2059[6]
EUG-MFR	2112-2132[6]
MFR-EUG	2157-2226[6]
EUG-PDX	2239-2304[6]

---

1 Assumes B-737 or DC-9 aircraft.

2 Optional continuation through Eugene to Portland requires two B-737 or DC-9 aircraft.

6 Except Saturday.

7 Except Sunday.

5.3.1. Available Seats

Third-level airlines operate weight-limited aircraft--aircraft that are limited on departure not by the number of seats, but by the weight they can carry. In effect then, the airline is not really selling seats, but fractions of its payload capacity measured in terms of available seats. Therefore, before an airline can select a tariff it must know how many seats it can actually sell.

Seats available are defined as:

$$AS = \frac{P}{PW}$$

where

AS is available seats,

P is the payload found in Section 3.2.4.6, and

PW is the average passenger weight. The FAA uses an average of 165 pounds for each adult passenger from November 1st to April 30th and 160 pounds from May 1st to October 31st. Children age two to twelve are taken as 80 pounds and those over twelve are considered adults; infants less than two years old are not counted. An additional five pounds is added for a hand bag for each passenger regardless of whether or not one is carried. Each piece of checked baggage is taken as 23.5 pounds.[67]

An analysis of data collected by British Airways European Division confirmed the FAA method, but revealed that checked baggage averaged five pounds less per passenger in winter than in summer--21 pounds per bag in winter and 26 pounds per bag in summer (average of one bag per passenger boarded). The mean weight of 191 pounds per adult passenger was arrived at as shown in Table 5-4. Children ages 2 to 12 could be offered discount fares because they could be boarded at 70% of adult fares and not affect revenue per pound, the best criterion on a weight-limited aircraft.

The mathematical rational for children's fares is given by:

$$\underset{(\text{IOCs})}{33\%} + \left[\frac{106+111}{2(191)}\right] \underset{(\text{DOCs})}{67\%} = 71.6\%$$

Children's bags were assumed to weigh the same as adult bags. Seventy percent would be exactly correct if children's bags average only 3 pounds lighter than adult bags.

5.3.2 Pricing Policy

When asked how they arrived at fares, the operators offered a variety of explanations. One used a straight rate-per-mile. Another used an

TABLE 5-4

AVERAGE PASSENGER WEIGHTS

	Winter November-April		Summer May-October	
	Adult	Child	Adult	Child
Passenger	165	80	160	80
Hand Bag	5	5	5	5
Bag	21	21	26	26
	---	---	---	---
TOTAL (pounds)	191	106	191	111

eight-dollar boarding fee plus a rate-per-mile. Two said fares were based on "what the market would bear." The last used the CAB standard class formula, 130% of coach fare, because 99% of its business was interline.

5.3.2.1 Differential Fares

The concept of differential pricing acknowledges that there is no optimum pricing policy for all circumstances. The airline can use differential fares to compete with other airlines and other modes of transportation, and to provide the different levels of service that different passengers require. There are two basic types of differential fares:

1. Cyclic differential fares attempt to smooth the demand peaks of seasonal, weekly, or daily cycles. Congestion tolls can be levied on travelers who, by their presence in the peak period, add more through congestion to marginal social costs than their perceived private costs.[68] The use of peak capacity at off-peak periods can be based on the marginal cost of providing the service. In low-density markets, the reduction in schedule delay for the service-conscious passenger that results from the stimulating effect of a low, off-peak fare may outweigh the cross-subsidy he pays during the peak periods.

2. Interpersonal differential fares attempt to separate consumers into categories, e.g., business, pleasure, military, group, family, youth, or length of stay, to exploit their different levels of marginal utility.

There are drawbacks with differential fares. There must be a net contribution after the inconvenience and administrative burden of a multiple pricing policy, the dilution of revenue by people willing to pay full-fare transferring to cheaper fares, and the marginal cost of production. Discount fares will burden the overall fare level in the long run if the fares don't cover the long-term marginal costs, and the airline plans to continue carrying the traffic. A simple method for determining, in theory, that the above requirements are met is given by:

$$Y + (1 - \eta)\, X \geq 1$$

where

Y is the differential fare in terms of the regular fare (%/100),

X is the fraction of traffic which is newly generated (%/100), and

η is the fraction of the regular fare required to cover the added noncapacity costs associated with the newly generated traffic, less any savings in cost attributable to the nature of services provided to the new traffic.

The problem is to correctly estimate X and η before the fare is instituted. This requires a detailed knowledge of the market. It is evident that the less generative effect a differential fare has the more the fare will need to cover fully allocated costs.[64]

Congestion pricing assumes that one group has a greater price-time cross-elasticity than another. If this is not the case then a price precipice may be hit before a meaningful shift occurs.[64] In the short-haul market there are strong indications that travel patterns are fixed in two diurnal peaks, before and after the workday. It has been estimated that 75% of local traffic and 40% of connecting traffic (50-60% of all traffic) will require prime-time flights and, hence, have a negligible price-time cross-elasticity.[17,69]

There are other problems with differential fares. If standby fares are offered on small aircraft operating at relatively high load factors, a passenger could book a sufficient number of seats under aliases to ensure a seat at the standby rate. Competitors may undercut the normal fare, which provides the cross-subsidy, to attract the high-yield traffic. Interpersonal differential fares are not held in high regard by either the public or the government. If the scheme requires enforcement, supervision may be time consuming and expensive. Lastly, fare complexity itself is an obstacle to travel.

Most third-level airlines practice some form of differential pricing to tap a market that would otherwise be inaccessible (Table 5-5).

5.3.2.2 Joint Fares

The division of joint fares between third-level carriers and certificated carriers is currently negotiated between the carriers. In some cases, the third-level airline gets a fixed dollar amount for each passenger, in others the third-level airline gets the full fare less a set amount, and sometimes the revenue is prorated, based on the contribution of each fare to the total. In any instance, the certificated carrier generally absorbs the majority of the dilution. The dilution of third-level revenues average approximately 15%.[17]

The Commuter Airline Association of America (CAAA) has petitioned the CAB (Docket 29707) to make mandatory joint-fares and division of fares between third-level and certificated carriers in accordance with the Domestic Passenger Fare Investigation (DPFI) phase 4, and to amend CAB part 298 to this effect. This, the CAAA contends, will enable passengers and communities to realize substantial benefits from all levels of service.[65] The certificated carriers oppose this citing that the CAAA did not wish to become a party to the DFPI during the original investigation and that, in most instances, it will dilute certificated fares even more. They also claim that the two types of airlines have different cost structures making DPFI phase 4 joint fares with third-level airlines inequitable.

Not all third-level carriers favor mandatory joint fares. In a market where the third-level airline has a monopoly, the prorating of joint fares can only result in a revenue loss. And, when joint tariffs are filed the third-level airline loses some of its exemptions under CAB

TABLE 5-5

THIRD-LEVEL AIRLINE PRICING POLICIES

Airline A	Airline B	Airline C	Airline D	Airline E	Airline F
Accompanied children @ 66% of full fare. Military Reservation.	Family Plan - One parent 100%. Second parent 75%, children aged 2-21, 50%. Under 2 free.	Family Plan - One parent 100%, second parent 50%, Children aged 12-21, 25%.	Group Fares for ten or more people.	Military Confirmed Reservation 75%.	No discounts
Extra bags $5 each (>2).	Without spouse oldest child, 12-21, pays 75%.	Group Fares for ten or more people: 80% one way, and 75% return.	Children & military discounts on request.	Additional baggage charge is proportional to fare.	
50 pound baggage limit & Sum-of-Dimensions limit.	Baggage Limits: Domestic or International Tourist 44 pounds (20 kg)	Children less than 12 years, 50%.	Extra baggage (>40 pounds), $0.10 per pound.		
		Military Standby 50%.			
		Youth Standby 50%.			
	First Class International 66 pounds (30 kg)	Evening Adult Standby 32%.			
		Baggage Sum-of-Dimension Limit.			

part 298. It must now:

1. Honor the schedule

2. Not discriminate against any passenger

3. Submit to the CAB's authority over the joint rate

4. Comply with liability insurance standards for certificated carriers

Because of the degree of cooperation planned with certificated carriers, particularly at Medford, joint fares were felt to be required. It was assumed that the joint fares were based upon DPFI phase 4 and that the certificated carriers would refuse to prorate revenue based on fares higher than those allowed certificated carriers. (The allowance of higher third-level fares would only increase the dilution of the certificated carrier.) The highest applicable rate is the standard class fare which is 130% of coach fare. This rate is available to local service carriers everywhere, but they rarely use it outside their monopoly markets.

5.3.2.3 Air Freight Pricing

Air freight service is generally considered more price elastic than passenger service.[69] This, coupled with the industry view that "as long as air freight revenue exceeds its costs it is making a contribution" has led to very low freight rates. Smith[63] found that air-freight yield per revenue-ton-mile is 49.3% of passenger yield.

In this study, freight fares were based on one-half of passenger fares or the marginal cost per pound-mile whichever was greater. Unfortunately no elasticities were available, Section 2.7.

Air freight is assumed shipped on a space-available basis. (This is discussed further in Section 5.3.3.2.4.) Any air freight requiring next flight service should be tariffed at the passenger rate (cost per pound = passenger fare/191 (pounds per passenger)).

5.3.3 Aircraft Loading

Aircraft cannot always serve the demand they generate. This section investigates the demand a third-level airline is likely to generate in comparision to the demand generated by certificated carriers because certificated carrier data was used to formulate the demand models. It then determines what fraction of that demand a third-level carrier may expect to serve.

5.3.3.1 The Ability of Third-level Airlines to Generate Demand

Two subjective ratings have been suggested to compare jet and nonjet equipment.[3,70] Three ratings have been suggested to compare traffic as a function of the number of stops to destination.[3,70,71] The CAB has found intermediate stops so detrimental to traffic that they have used them to prevent local service carriers from competing with trunks. Then, in the route-strengthening program, they removed the intermediate stop requirement to reduce subsidy needs. These ratings suggest that a third-level airline, operating nonjet equipment and having multiple stops, would not generate the traffic of a certificated carrier. (A third-level carrier would be expected to average more stops over a given route because smaller cities would be more profitable when served by the smaller aircraft of a third-level airline.) One study[9] found that third-level carriers generate only 73.1% of the passengers of certificated carriers, but the Allegheny Commuter Program demonstrated that this was only true in competitive situations. In a monopoly market, these factors did not affect demand.[72]

The proposed route system does not have any intra-market stops or competing carriers, and the connecting travel demand model uses the number of seats per departure (aircraft size) as proxy for other things, e.g. the number of nonstop destinations, jet equipment. Therefore, travel demand is not modified because of type of service or equipment.

5.3.3.2 Demand Served

Elle[73] has developed a method to determine the fraction of demand served.

5.3.3.2.1 Flight Demand

Passengers are assumed to arrive randomly for a flight in groups of 1.3-1.4 passengers. This can be represented by the Poisson distribution. If no long-term effects are present, the variation of long-term travel demand is the sum of several Poisson distributions which is itself a Poisson distribution of greater mean value.

The standard deviation of the Poisson distribution, σ_1, is equal to the square root of the mean $(\mu_1)^{0.5}$. Therefore, the relative spread is proportional to the inverse of the square root of the mean $(\mu_1)^{-0.5}$. This implies that the influence of chance on demand fluctuations is only a function of the mean demand per flight, and the relative influence of chance decreases with increasing mean demand per flight. Hence, the effects of chance are more dominant when air travel demand per flight is small. Therefore, for a given passenger-group refusal rate, an aircraft with fewer seats available must operate at a lower mean load factor than an aircraft more seats.

The probability function of a Poisson distribution is given by:

$$f(x,\mu_1) = e^{-\mu_1} \frac{\mu_1^{x}}{x!}$$

$$(x = 0,1,2,3,\ldots\ldots)$$

where

$f(x,\mu_1)$ is the probability of x passenger groups.

5.3.3.2.2 Seasonal Demand

A distribution to represent seasonal and nonseasonal factors must

1. Cover the interval from zero to infinity because demand cannot be negative, but it could increase to infinity (with an appropriately low probability).

2. Contain at least two variables because the amplitude of the basic demand and the amplitude of the fluctations are mutually independent variables.

The gamma, Γ, distribution meets these requirements, as do some others, and has a probability function:

$$f(x,a,P) = \frac{x^{P-1}}{a^P \Gamma(P)} e^{-(x/a)}$$

$$(x = 0,1,2,3,......)$$

where

x is the magnitude of the demand per flight (passenger groups), and

a,P are arbitrary constants associated with the traffic environment such that the mean demand, μ_2, equals Pa, the standard deviation, σ_2, equals $(Pa^2)^{0.5}$, and the ratio of the standard deviation to the mean is $P^{-0.5}$.

$P^{-0.5}$ represents the seasonal fluctuation. Seasonal fluctuation is computed from Hughes Airwest internal monthly summaries. It is first necessary to remove the effects of traffic growth by regression:

$$T_m = K1 + K2\ m$$

where

T_m is the forecast traffic in month m,

K1 is the intercept,

K2 is the monthly growth rate of the station, and

m is the time in months.

The seasonal fluctation is then found from:

$$P^{-0.5} = \left(\frac{M \sum_{m=1}^{M} (T_{am} - T_m)^2}{\sum_{m=1}^{M} T_{am}} \right)^{0.5}$$

where

T_{am} is the actual traffic in month m,

T_m is the forecast traffic in month m, and

M is the months in the sample.

5.3.3.2.3 Passenger Demand Served Per Flight

When the gamma distribution is superimposed on the Poisson distribution it becomes the negative binomial distribution whose probability function is given by:

$$f(x,a,P) = \left(\frac{x + P - 1}{x}\right) \left(\frac{a}{a + 1}\right)^{x} \left(\frac{1}{a + 1}\right)^{P}$$

$$(x = 0,1,2,3,......)$$

where

f(x,a,P) is the probability of a demand for x passenger groups per flight.

The mean is the same as for the Poisson and gamma distribution

$$\mu_1 = \mu_2 = Pa,$$

but the standard deviation is greater due to the effects of chance

$$\sigma_3{}^2 = (\sigma_1{}^2 + \sigma_2{}^2) = (Pa + Pa^2).$$

Given the aircraft size (number of seats, X'), 1.35 passengers per group, the mean demand per flight ($\mu_1 = \mu_2 = Pa$), and the seasonal fluctuations ($P^{-0.5}$), the mean number of passenger groups served per flight is given by:

$$\mu_X = \left(\sum_{x=0}^{X} x\, f(x,a,P)\right) + \left(1 - \sum_{x=0}^{X} f(x,a,P)\right)X$$

where

X = X'/1.35 (X is rounded down to the next lower integer).

The fraction of traffic served is (μ_X/Pa). The mean number of passengers served per flight is given by:

$$\mu'_X = 1.35(\mu_X).$$

No-shows are a function of the route, journey type, season, day of the week, and time of day. They average 5-10% of all bookings and in some markets may reach 25%.

No-shows have the greatest detrimental effect on short-haul routes and on routes with frequent, competitive service because there is other transport are available. People book more than one flight both to ensure a seat and in case their preferred departure time changes. This practice makes the flights artificially full which leads to more seat-ensurance booking. The airlines counter this practice by giving standby reservations.

If N represents the fraction of no-show traffic and the airline wishes to account for all the no-shows by overbooking, it can book $(1/(1-N))$ passengers. The airline can use the negative binomial distribution to estimate the new mean demand served per flight by artificially increasing the number of seats by the same factor. The mean demand served per flight becomes μ''_x passengers, not passenger groups.

The passengers per flight holding confirmed reservations and being denied a seat may be estimated from:

$$\left[\frac{N}{1-N}\right] \mu'_x - \mu''_x$$

Aircraft size is not increased in this analysis to account for no-shows because the effects of reliability demonstrated that a passenger had to be assured of a seat with a confirmed booking.

5.3.3.2.4 Air Freight Demand Served

Air freight was assumed, by the computer program, to be available at the beginning of the day for a space-available departure throughout the day. And, air freight demand was assumed to be Poisson distributed. The average parcel weight was computed from British Caledonian Airways data sheets. The analysis was limited to packages under 300 pounds--a common third-level airline limit without special arrangement. The average package weight was found to be 28 pounds. Limitations on the size of number that the computer could handle ($\cong 10^{76}$) restricted parcels per day to 56 ($56! \cong 7 \cdot 10^{74}$). Therefore, when air freight demand per day exceeded 1568 pounds:

$$SW = \frac{FR8D}{56}$$

where

SW is the new average package weight (pounds), and

FR8D is the pounds of air freight shipped per day.

The mean demand served comes from the Poisson distribution (x, μ_1):

$$\mu'_1 = \left(\sum_{x=1}^{Np} x\ f(x,\mu_1)\right) + \left(1 - \sum_{x=1}^{Np} f(x,\mu_1)\right)Np$$

where

μ'_1 is the mean number of parcels served per day,

μ_1 is the mean daily parcel demand, and

Np is the number of parcels that can be loaded. It is determined from the excess payload capacity in pounds, after the passengers are boarded, divided by:

$$\text{Min}\left\{56, FR8D/28\right\}.$$

The daily air freight carriage, DF, then is

$$DF = \mu'_1 \text{ Max}\left\{28, SW\right\},$$

and the percentage of freight demand served is

$$\frac{DF}{FR8D} 100.$$

5.3.4 Other Inputs to the Computer Program

The remainder of the inputs to the route selection and pricing program are described below.

5.3.4.1 Reliability

Mechanical reliability is defined as:

$$\frac{S-D}{S}$$

where

S is the scheduled number of departures, and

D is the departures delayed 15 minutes or more for non-meteorological reasons.

Five third-level air carriers reported mechanical reliabilities (or others) of: 97-99%, 99.1%, "not allowed", 96% (4% intentional cancellations because of a lack of traffic), and 100% (3%, all weather-related). Allegheny reports that its twelve Allegheny Commuters have a completion factor of 97% for all causes.[72]

An analysis of the internal performance reports of two third-level airlines showed an aircraft reliability of 98.5%, with a reserve aircraft this became effectively 99.25% (Table 4-6). The 99.25% value was used for mechanical reliability.

The meteorological completion factors are the fraction of the time that the flight can land within 15 minutes of the scheduled arrival time, Section 5.2.

Reliability, for the intra-Oregon travel demand model and for modifying scheduled departures to completed departures in both the connecting travel demand model and the air freight demand model, is the average of the route inbound and outbound meteorological factors multiplied by the mechanical reliability.

Completed departures is the reliability multiplied by days in the year multiplied by the flights per weekday multiplied by a factor of less than one to account for the flights not scheduled on the weekends.

5.3.4.2 Frequency Factors and Connecting Travel Factors

Frequency factors are determined for each individual flight, as discussed in Section 2.5. (Once scheduling is complete, the frequency factors are not modified by the meteorological factors; meteorological factors are specifically accounted for by reliability.) Weighted-average frequency factors for flights between Portland and Medford are shown in Figure 5-3 A, B, C and D.

The variation of connecting travel demand throughout the day was found from analyzing the "Domestic City Pair Summary"[27] to determine the destination cities that received 1% or more of the passengers from a station. Then the OAG was consulted to determine the average time between local departure and local arrival for passengers departing from Oregon and for passengers arriving in Oregon. Lastly, the Boeing demand curves were weighted according to the arriving or departing passenger demand for their time difference interval.[30]

The composite curves that result from the weightings are shown for arrivals and departures in Figure 5-4. Note that departure demand peaks in the morning and arrival demand peaks in the afternoon. This is as expected.

Next the connecting demand profiles are apportioned between the flights. The area under each curve is one, and each flight is given the fraction of traffic represented by the area under the curve from one-half the time back to the previous flight until one-half the time to the next flight. The curves and representative apportionment for flights over Oregon routes between Portland and Medford are shown in Figure 5-5A, B, C, and D. Northern departures (arrivals) are through Portland and southern departures (arrivals) through Medford. Again, the curves don't affect connecting travel demand; they only allocate it among the flights. The fractions for both arrivals and departures must total one--the frequency factors for intra-Oregon demand would do so only with infinite frequency.

5.3.5 Summary of Route Selection and Pricing Program Inputs

Table 5-6 gives the computer inputs in the order they are required and references for additional data.

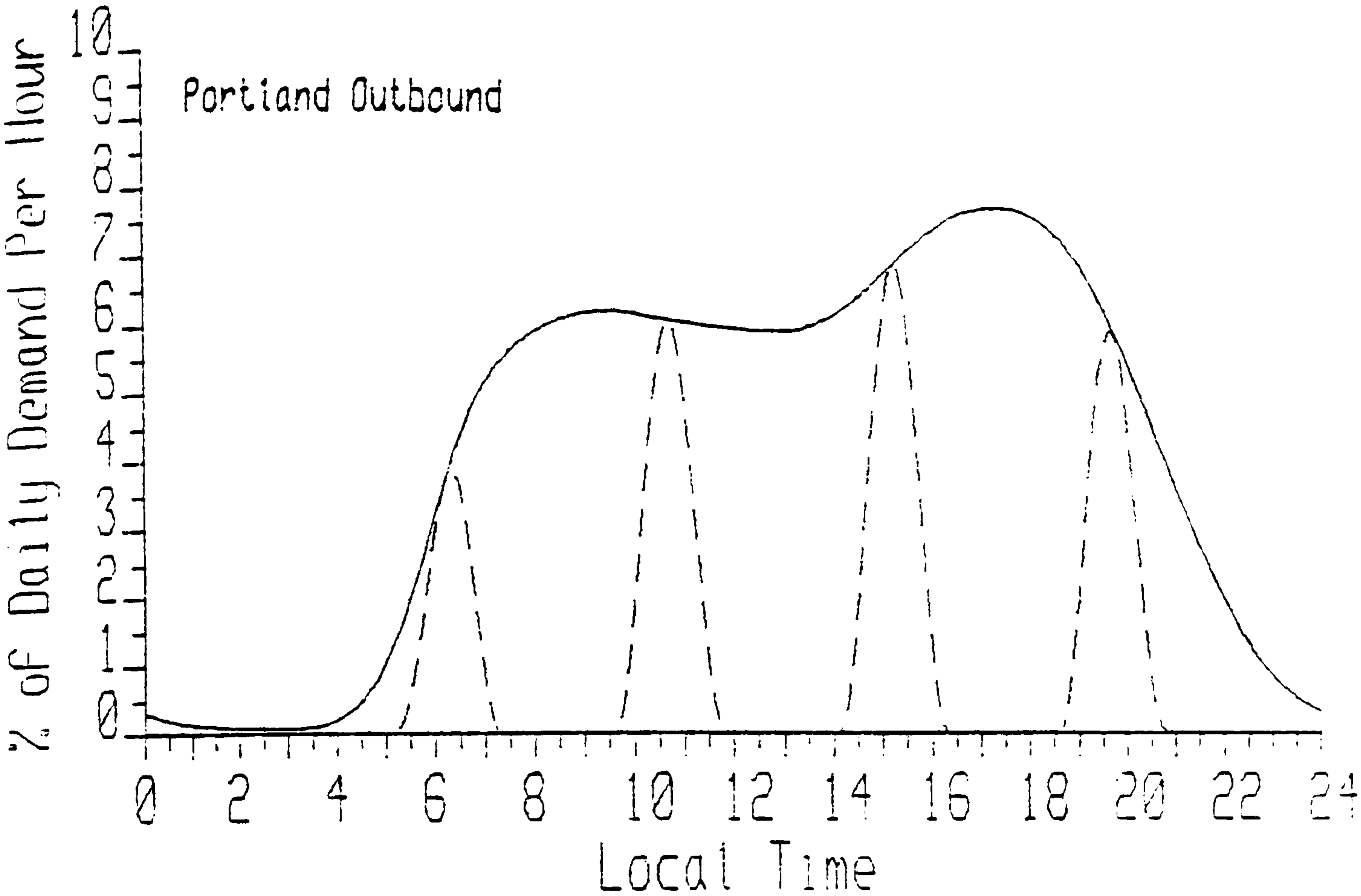
5.3.6 The Objective Function

The function to be maximized is contribution, defined by:

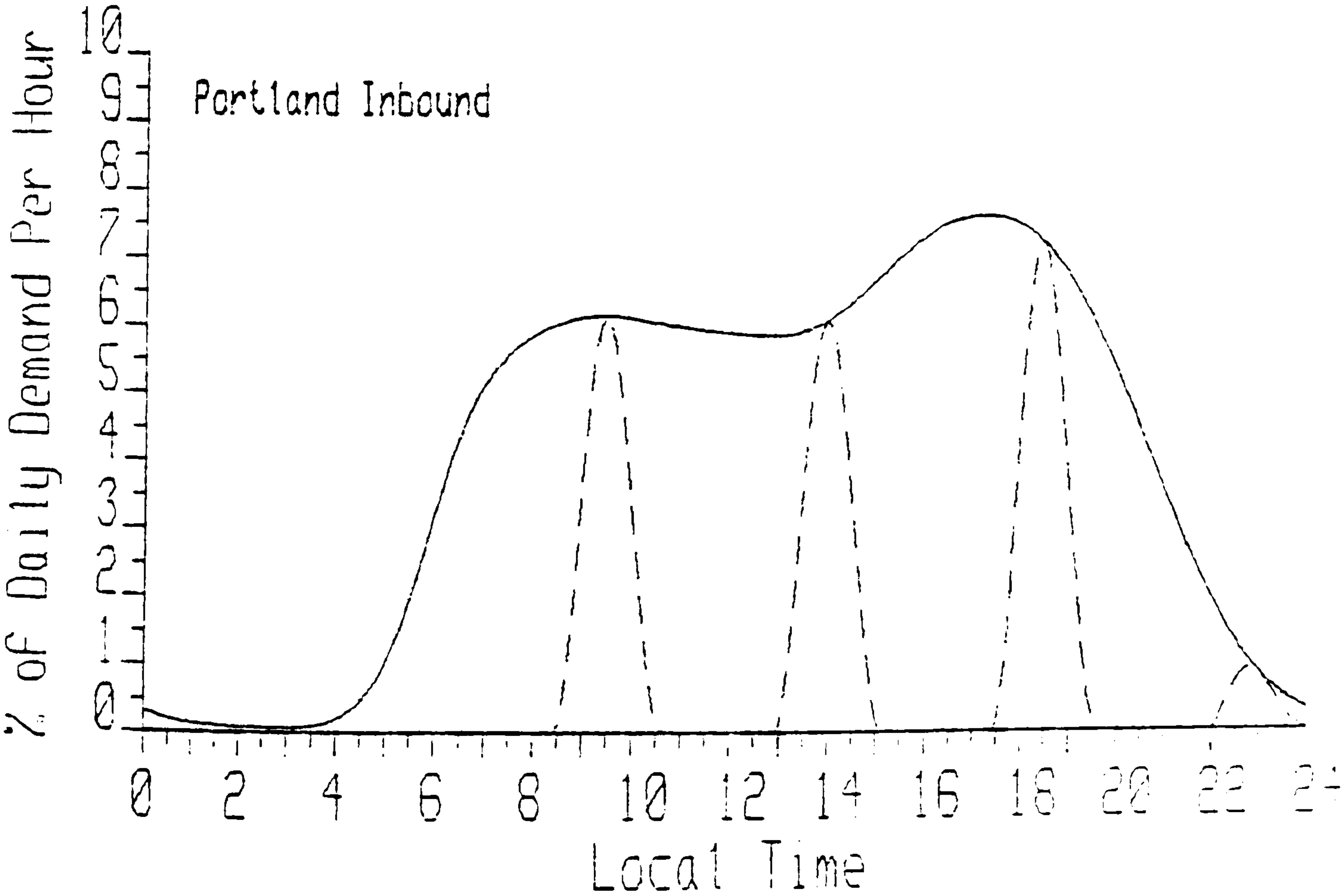
$$\text{Max}\left\{\text{Con}\right\} = \text{Max}\left\{ \left[K_1\ \text{OP}\ F + K_1\ K_2\ \text{CP} + \text{Max}\{K_3, K_4\}\,\text{FR8}\right] - \left[\text{TC} + (\text{OP} + \text{CP} + \text{FR8/PW})\ \text{CPM}\ D\right] \right\}$$

where

Con is the contribution,

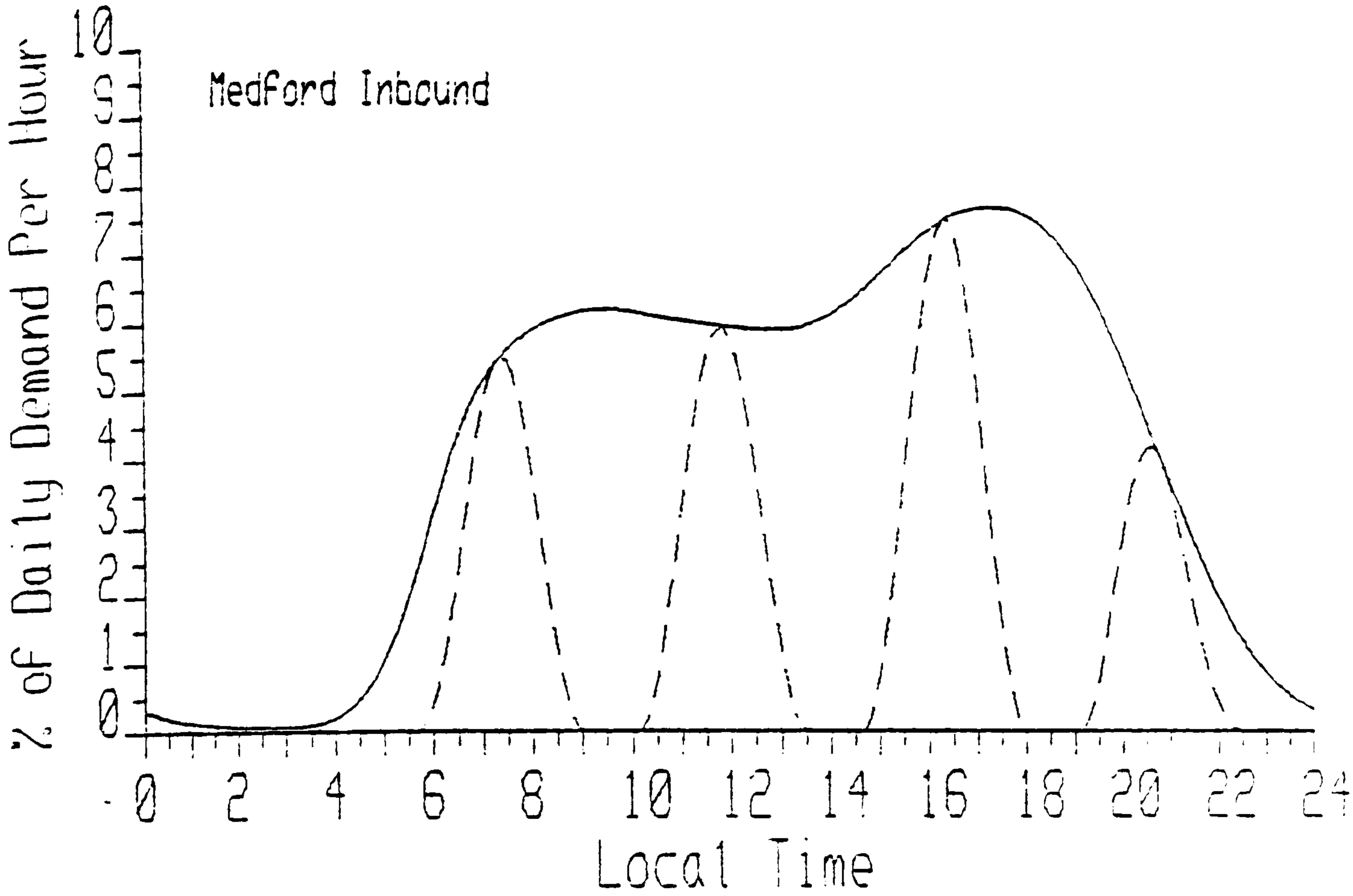


(A)

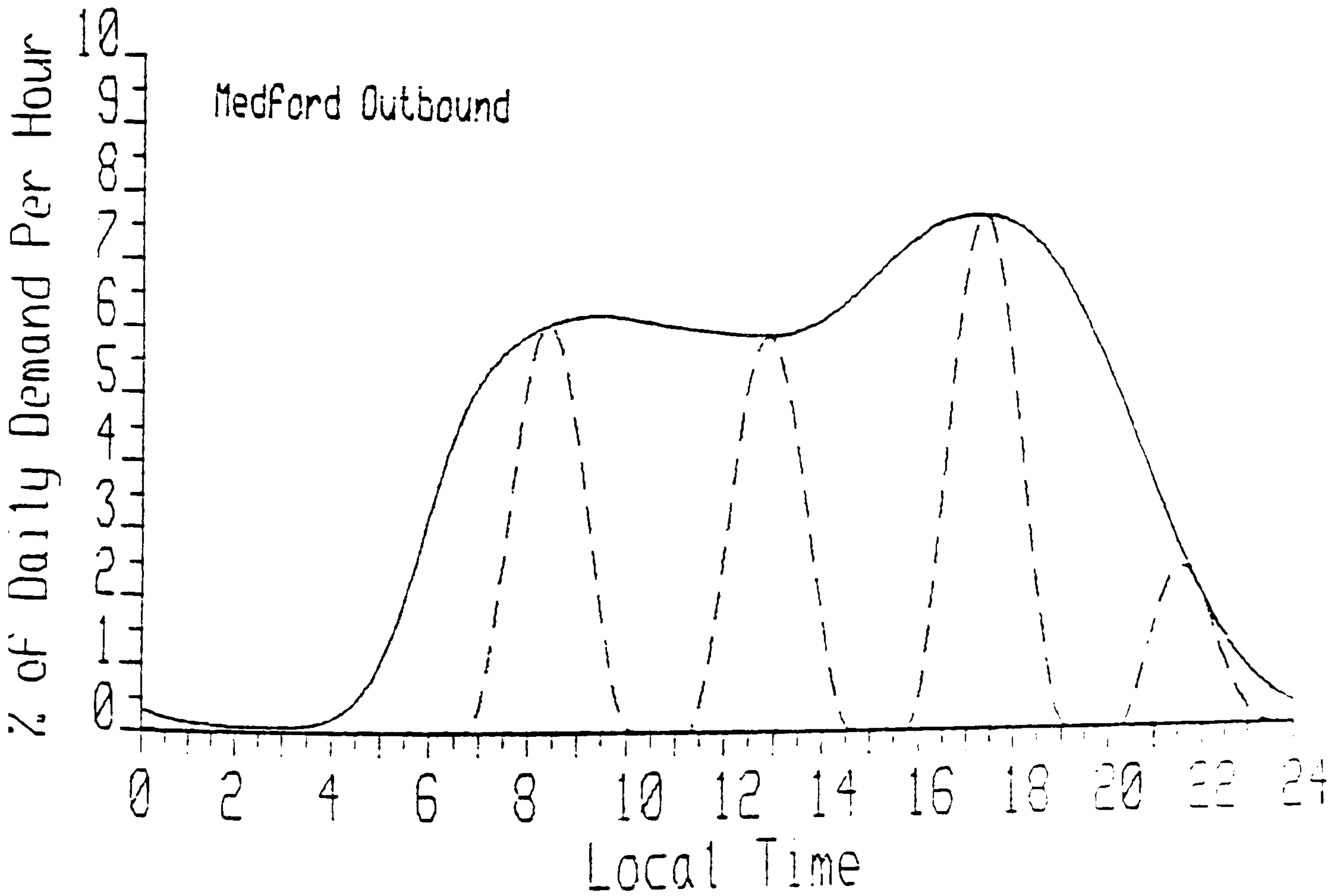


(B)

FIGURE 5-3
LOCAL DEMAND BY FLIGHT



(C)



(D)

FIGURE 5-3
LOCAL DEMAND BY FLIGHT
(CONTINUED)

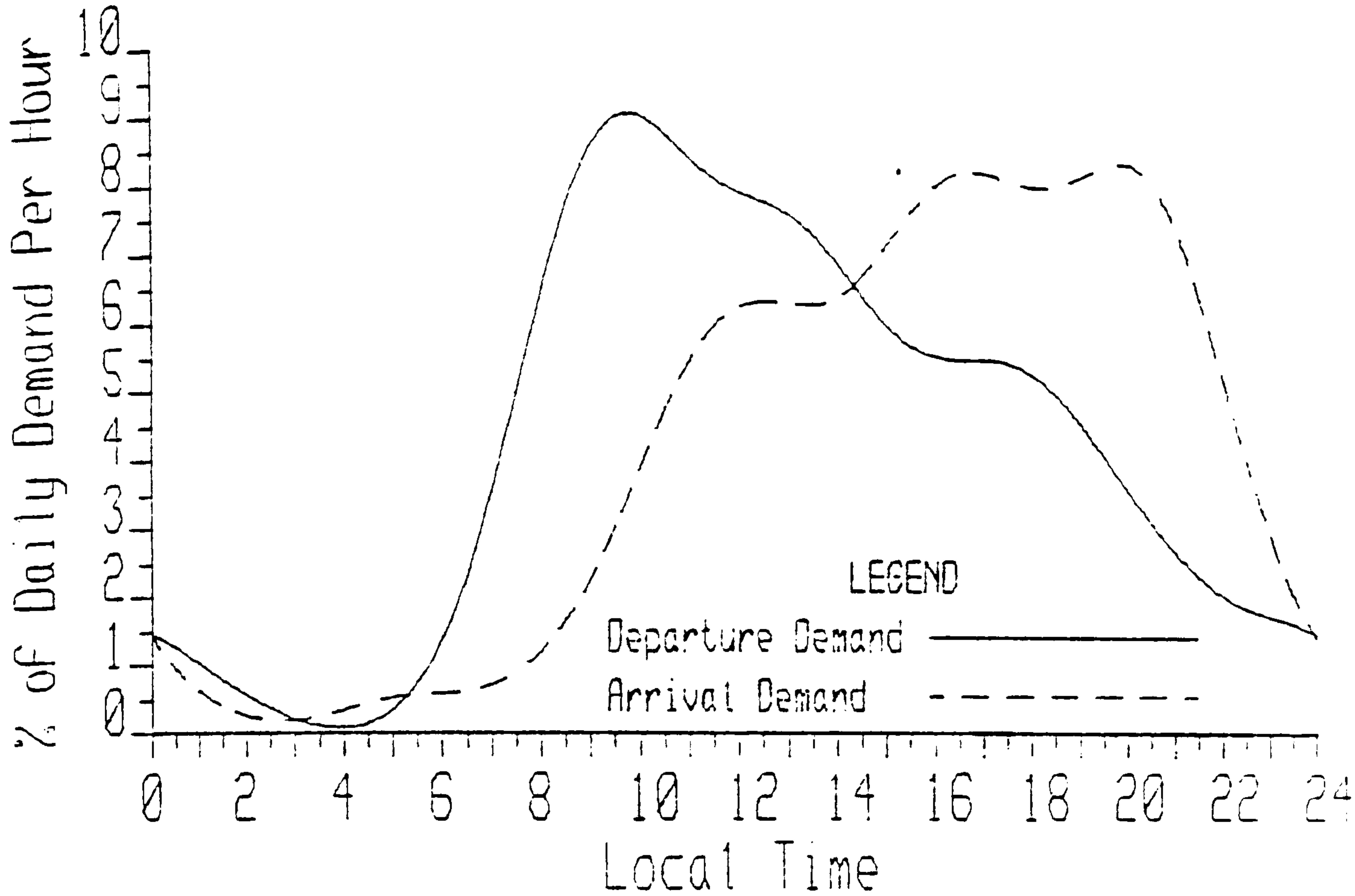
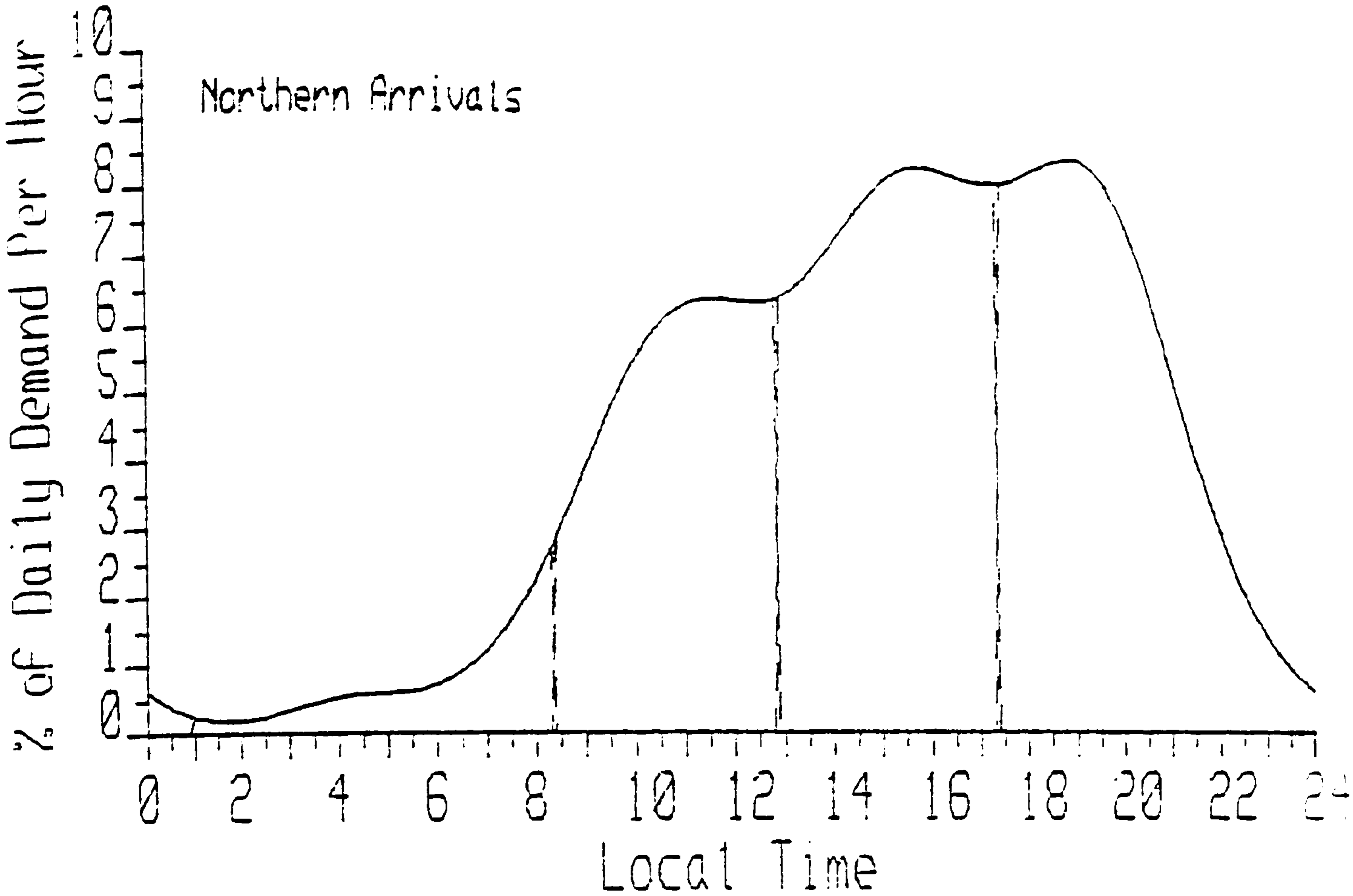
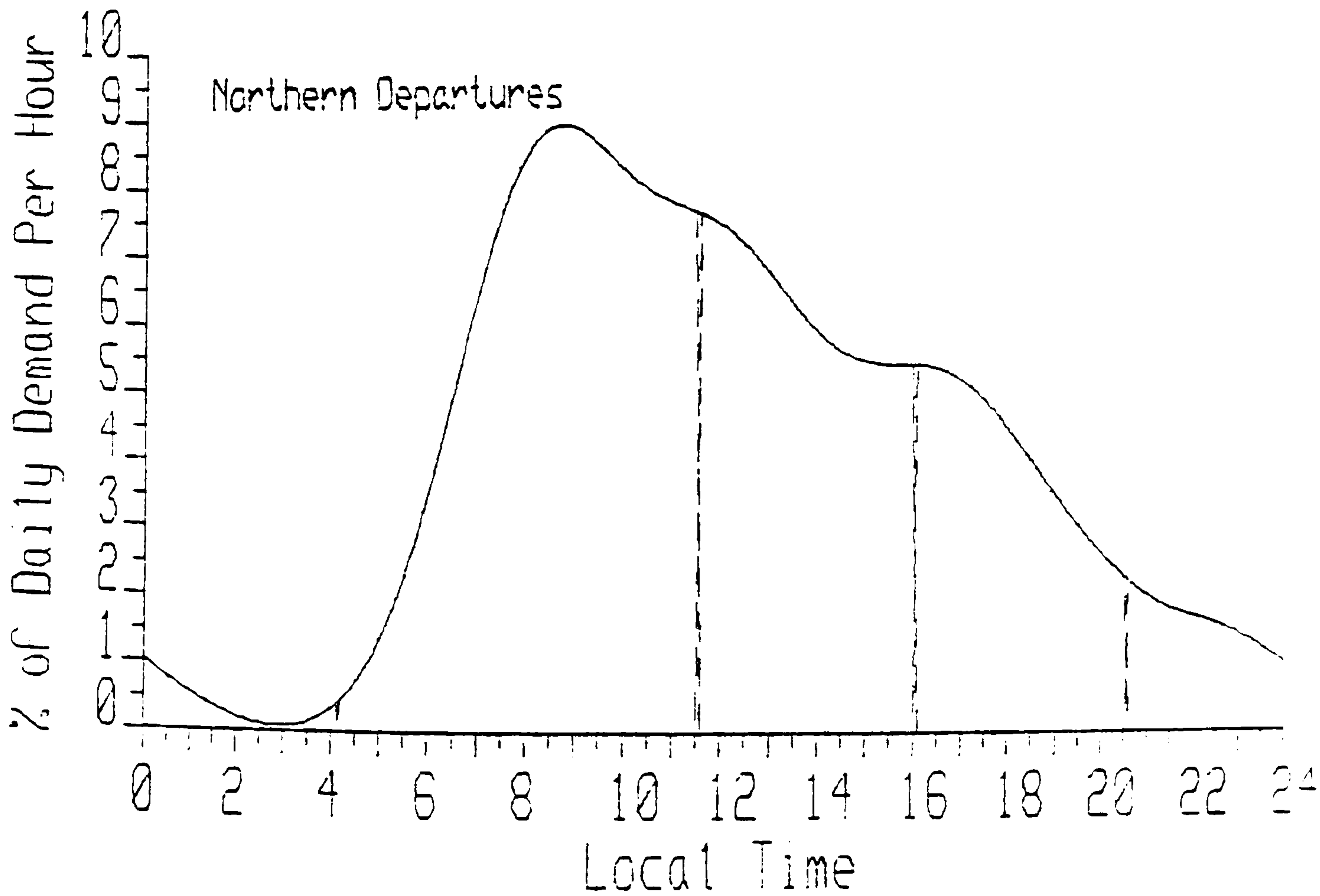


FIGURE 5-4
CONNECTING DEMAND PROFILES

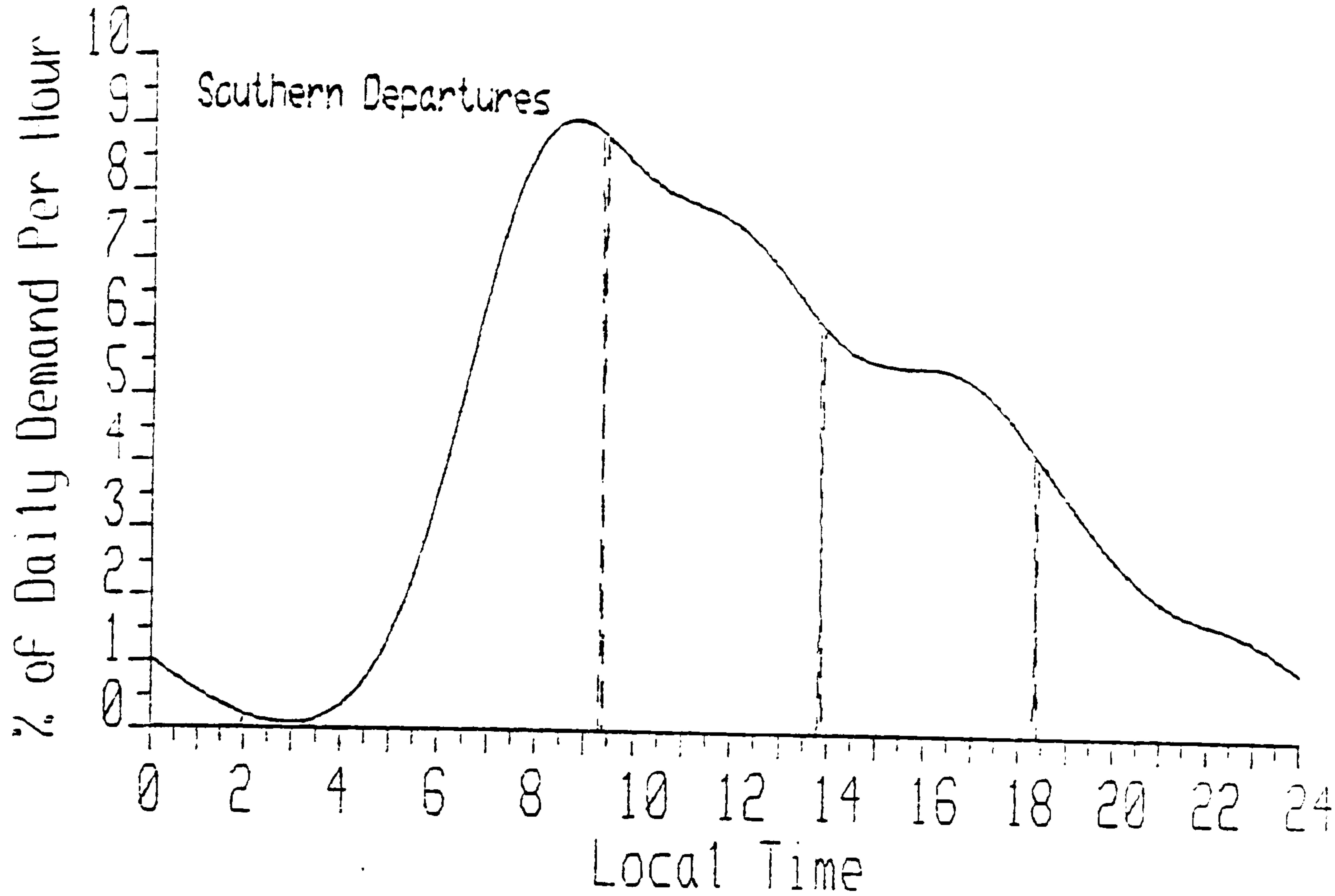


(A)

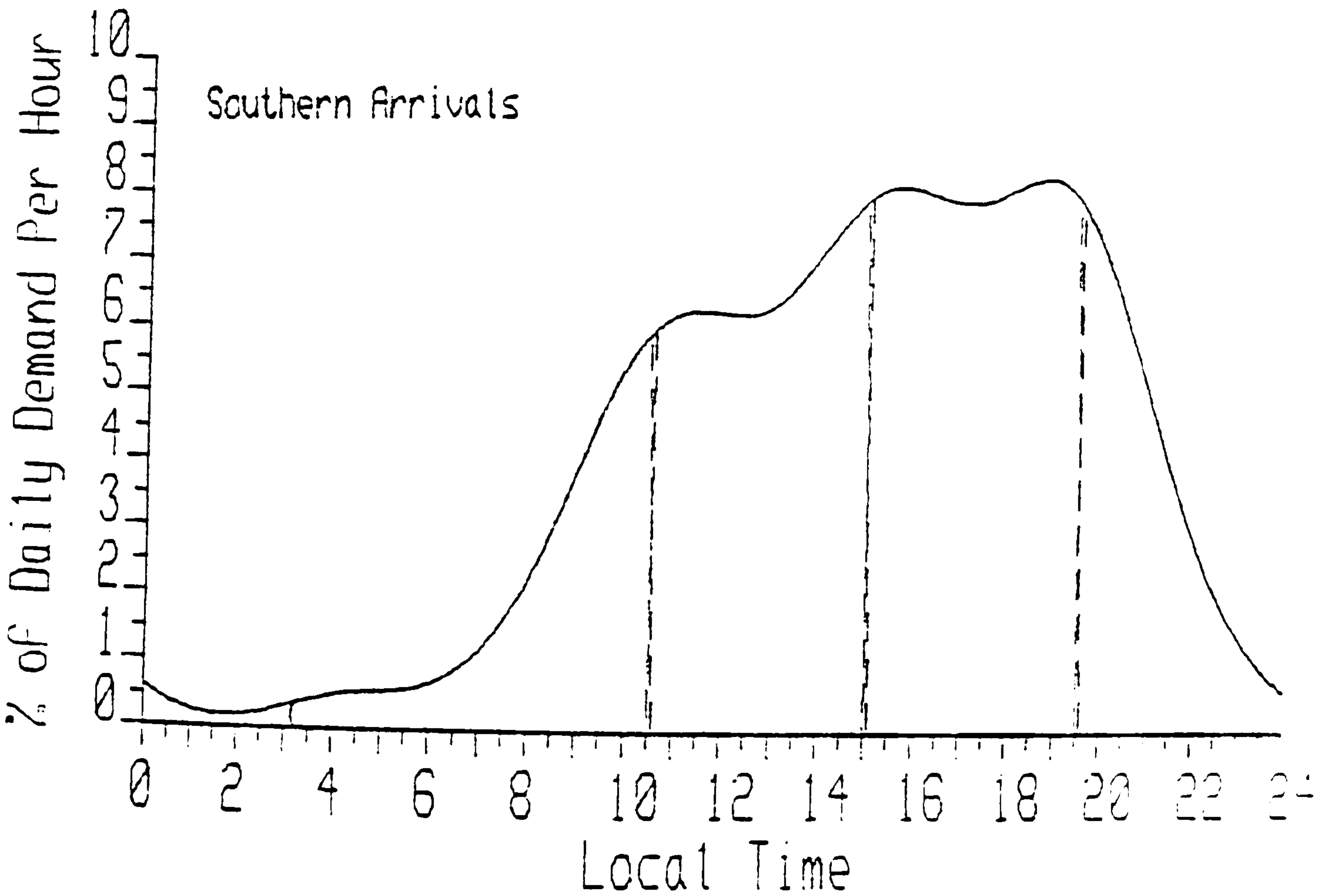


(B)

FIGURE 5-5
CONNECTING DEMAND BY FLIGHT



(C)



(D)

FIGURE 5-5
CONNECTING DEMAND BY FLIGHT
(CONTINUED)

TABLE 5-6

ROUTE SELECTION AND PRICING PROGRAM INPUTS

Airline Systemwide Data

Year of operation (1978 or 1987)
Mechanical reliability of aircraft (Section 5.3.4.1)
Marginal cost per RPM ($) (Section 5.3.6)
Mean weight of air freight packages (lbs) (Section 5.3.3.2.4)

Station Data

Station type (1, Pendleton or Baker-La Grande; 0, all others)
Flights/route/day adjusted to flights/week by program (4=26/28,6=38/42)
Tax returns (000s) in air service area (Section 2.6)
Time to Portland (Hours x 10; ΔT) (Section 2.6)
Mean journey length from station (Section 5.3.6)
Station name

Route Data

Connecting traffic fraction FS, 1-FS (Section 2.6.1)
Block time (Hours) (Section 3.2.4.6)
Stage length (sm)
Seats available (Section 5.3.1)
PIM (Section 2.5)
Seasonal fluctuations, $P^{-0.5}$ (Section 5.3.3.2.1)
$(DP)^{K5}$ (Section 2.5)
Average of outbound and inbound trip cost less pilot and mechanic RPM component (Section 3.6)
Name of station at the other end (Portland or Medford)
Fraction of freight forecast inbound (Section 2.7)
Fraction of freight forecast outbound (Section 2.7)
Frequency factors per flight inbound (Section 5.3.4.2)
Frequency factors per flight outbound (Section 5.3.4.2)
Fraction of connecting traffic per flight inbound (Section 5.3.4.2)
Fraction of connecting traffic per flight outbound (Section 5.3.4.2)
Meteorological completion factors inbound (Section 5.2)
Meteorological completion factors outbound (Section 5.2)

K1 (0.92) is the fraction of revenue remaining after the ticket tax (8%),

OP is the number of intra-Oregon passengers served,

F is the fare to be found,

CP is the number of connecting passengers served,

K2 is the third-level airline's share of the revenue based on DPFI phase 4 joint fares:

$$K_2 = \frac{(F + L_1 - L_2 + (DD\text{-}D\text{-}500)\ L_3)(L_4 + L_5\ D)}{(2\ L_4 + L_5\ DD)}$$

where

L_1($68.41) is the forecast coach fare, in 1978 dollars, for a flight of 500 sm,

L_2($4) is the savings, in 1978 dollars, over the normal boarding charge that the CAB found in DPFI phase 4,

DD is the mean journey length originating from the station (The mean journey length from station was found from "Domestic City-Pair Summary"[27] and computed by dividing revenue-passenger-miles originating at the station by the passengers boarded at the station. The range is 802-1190 sm for the Oregon stations.),

D is the applicable stage length of the third-level carrier (The range is 51-240 sm for the Oregon stations.),

L_3($0.0720) is the forecast coach fare rate per mile, in 1978 dollars, for the distance between 500 and 1500 sm,

L_4(17.52) is the boarding charge in units, the important item here is its size relative to L_5, not its value (DPFI phase 4),

L_5(0.0358) is the rate per mile in units, see L_4, and

K_3 is the air freight revenue defined by:

$$\frac{M1\ M2\ F}{PW}$$

where

M1(0.95) is the fraction of revenue remaining after the air freight tax (5%),

M2(0.5) is the fraction of the passenger fare (F) charged for air freight, PW (191) is the mean passenger weight in pounds, and

K_4 is the air freight revenue defined by:

$$\frac{CPM\ D}{PW}$$

where

CPM is the marginal cost per revenue-passenger-mile (IOC costs plus pilot and mechanic RPM component) of $0.07941 in 1978 and $0.08899 in 1985, both in 1978 dollars,

FR8 is the air freight weight in pounds, and

TC is the direct operating cost of the trip (see Figure 3-5) minus the component of pilot and mechanic salaries attributed to revenue-passenger-miles.

The decision to add or delete a city was based on whether or not the sum of the prospective routes of the city had a positive contribution. It was necessary in two instances to serve routes with negative contributions in order to serve other routes with positive contributions; the total contribution was positive in both cases.

5.4 Route Selection and Pricing Results

5.4.1 Route and Station Statistics

The pricing and route selection program was run and stations selected on the basis of their contribution. The steady-state solutions (mature demand, mature airline) for the routes and stations for the years 1978 and 1987 are given in Tables 5-7 to 5-20. All stations have routes to Portland and Medford except Pendleton and Baker-La Grande which only have routes to Portland. The tables are explained below.

The intra-Oregon, connecting, and total passengers per year are self-explanatory.

The ticket price in 1978 dollars is the standard-class ticket price because most of the traffic is connecting. Connecting traffic and air freight are price inelastic and the joint-fares proration also favors a high fare. There are two exceptions, North Bend-Coos Bay to Portland and Klamath Falls to Portland. Intra-Oregon traffic on these routes is 75% of total traffic and the intra-Oregon price elasticity has an effect. Redmond-Bend's 1978 Portland traffic is 66% of route traffic and standard-class fares are unaffected. The real cost increases between 1978 and 1987 of 10.5% in the North Bend-Coos Bay to Portland market and 9% in the Klamath Falls to Portland market cause real ticket prices to rise such that intra-Oregon traffic decreases during the time period.

TABLE 5-7 CORVALLIS-ALBANY-1978

STATION: CORVALLIS-ALBANY, OREGON

FLIGHTS TO PORTLAND, OREGON

PASSENGER DATA:		
LOCAL PASSENGERS PER YEAR		1526
CONNECTING PASSENGERS PER YEAR		5781
TOTAL PASSENGERS PER YEAR		7307
TICKET PRICE		$33.00
STANDARD CLASS TICKET PRICE		$33.00
AVERAGE LOAD FACTOR - PASSENGER		15.20%
PERCENTAGE OF PASSENGER DEMAND SERVED		97.02%
MAIL AND FREIGHT DATA:		
FREIGHT PER YEAR - POUNDS		743732
FREIGHT RATE PER POUND		$0.082
PERCENTAGE OF FREIGHT DEMAND SERVED		100.00%
REVENUE (AFTER TICKET TAX):		
LOCAL TRAFFIC REVENUE	$	46342
CONNECTING TRAFFIC REVENUE	$	193481
FREIGHT REVENUE	$	61036
TOTAL REVENUE	$	300859
CONTRIBUTION	$	-30236
TRIP DISTANCE (SM)		83.0
FLIGHT RELIABILITY		96.13%

FLIGHTS INBOUND:	
LOAD FACTOR ON FLIGHT - 1	5.10%
LOAD FACTOR ON FLIGHT - 2	13.47%
LOAD FACTOR ON FLIGHT - 3	19.36%
LOAD FACTOR ON FLIGHT - 4	23.26%
FLIGHTS OUTBOUND:	
LOAD FACTOR ON FLIGHT - 1	23.98%
LOAD FACTOR ON FLIGHT - 2	18.18%
LOAD FACTOR ON FLIGHT - 3	14.45%
LOAD FACTOR ON FLIGHT - 4	3.80%

YEAR OF OPERATION: 1978

FLIGHTS TO MEDFORD, OREGON

PASSENGER DATA:		
LOCAL PASSENGERS PER YEAR		2561
CONNECTING PASSENGERS PER YEAR		14573
TOTAL PASSENGERS PER YEAR		17134
TICKET PRICE		$41.00
STANDARD CLASS TICKET PRICE		$41.00
AVERAGE LOAD FACTOR - PASSENGER		37.52%
PERCENTAGE OF PASSENGER DEMAND SERVED		99.80%
MAIL AND FREIGHT DATA:		
FREIGHT PER YEAR - POUNDS		0
FREIGHT RATE PER POUND		$0.102
PERCENTAGE OF FREIGHT DEMAND SERVED		100.00%
REVENUE (AFTER TICKET TAX):		
LOCAL TRAFFIC REVENUE	$	96593
CONNECTING TRAFFIC REVENUE	$	559079
FREIGHT REVENUE	$	0
TOTAL REVENUE	$	655672
CONTRIBUTION	$	121762
TRIP DISTANCE (SM)		148.0
FLIGHT RELIABILITY		94.93%

FLIGHTS INBOUND:	
LOAD FACTOR ON FLIGHT - 1	22.57%
LOAD FACTOR ON FLIGHT - 2	40.89%
LOAD FACTOR ON FLIGHT - 3	52.87%
LOAD FACTOR ON FLIGHT - 4	32.53%
FLIGHTS OUTBOUND:	
LOAD FACTOR ON FLIGHT - 1	33.91%
LOAD FACTOR ON FLIGHT - 2	52.22%
LOAD FACTOR ON FLIGHT - 3	39.65%
LOAD FACTOR ON FLIGHT - 4	25.53%

CONTRIBUTION OF CORVALLIS-ALBANY, OREGON :$ 91526

TABLE 5-8 CORVALLIS-ALBANY-1987

STATION: CORVALLIS-ALBANY, OREGON

FLIGHTS TO PORTLAND, OREGON		
PASSENGER DATA:		
LOCAL PASSENGERS PER YEAR		1822
CONNECTING PASSENGERS PER YEAR		6567
TOTAL PASSENGERS PER YEAR		8389
TICKET PRICE		$33.00
STANDARD CLASS TICKET PRICE		$33.00
AVERAGE LOAD FACTOR - PASSENGER		18.26%
PERCENTAGE OF PASSENGER DEMAND SERVED		97.02%
MAIL AND FREIGHT DATA:		
FREIGHT PER YEAR - POUNDS		849389
FREIGHT RATE PER POUND		$0.082
PERCENTAGE OF FREIGHT DEMAND SERVED		100.00%
REVENUE (AFTER TICKET TAX):		
LOCAL TRAFFIC REVENUE		$ 55303
CONNECTING TRAFFIC REVENUE		$ 219802
FREIGHT REVENUE		$ 69707
TOTAL REVENUE		$ 344812
CONTRIBUTION		$ -27933
TRIP DISTANCE (SM)		83.0
FLIGHT RELIABILITY		96.13%
FLIGHTS INBOUND:		
LOAD FACTOR ON FLIGHT - 1	6.21%	
LOAD FACTOR ON FLIGHT - 2	16.22%	
LOAD FACTOR ON FLIGHT - 3	23.24%	
LOAD FACTOR ON FLIGHT - 4	27.85%	
FLIGHTS OUTBOUND:		
LOAD FACTOR ON FLIGHT - 1	28.74%	
LOAD FACTOR ON FLIGHT - 2	21.84%	
LOAD FACTOR ON FLIGHT - 3	17.45%	
LOAD FACTOR ON FLIGHT - 4	4.55%	

YEAR OF OPERATION: 1987

FLIGHTS TO MEDFORD, OREGON		
PASSENGER DATA:		
LOCAL PASSENGERS PER YEAR		3144
CONNECTING PASSENGERS PER YEAR		16500
TOTAL PASSENGERS PER YEAR		19644
TICKET PRICE		$41.00
STANDARD CLASS TICKET PRICE		$41.00
AVERAGE LOAD FACTOR - PASSENGER		45.14%
PERCENTAGE OF PASSENGER DEMAND SERVED		99.47%
MAIL AND FREIGHT DATA:		
FREIGHT PER YEAR - POUNDS		0
FREIGHT RATE PER POUND		$0.102
PERCENTAGE OF FREIGHT DEMAND SERVED		100.00%
REVENUE (AFTER TICKET TAX):		
LOCAL TRAFFIC REVENUE		$ 118583
CONNECTING TRAFFIC REVENUE		$ 632992
FREIGHT REVENUE		$ 0
TOTAL REVENUE		$ 751575
CONTRIBUTION		$ 130773
TRIP DISTANCE (SM)		148.0
FLIGHT RELIABILITY		94.93%
FLIGHTS INBOUND:		
LOAD FACTOR ON FLIGHT - 1	27.56%	
LOAD FACTOR ON FLIGHT - 2	49.27%	
LOAD FACTOR ON FLIGHT - 3	63.24%	
LOAD FACTOR ON FLIGHT - 4	38.99%	
FLIGHTS OUTBOUND:		
LOAD FACTOR ON FLIGHT - 1	40.96%	
LOAD FACTOR ON FLIGHT - 2	62.37%	
LOAD FACTOR ON FLIGHT - 3	47.92%	
LOAD FACTOR ON FLIGHT - 4	30.86%	

CONTRIBUTION OF CORVALLIS-ALBANY, OREGON :$ 102840

TABLE 5-9 KLAMATH FALLS-1978

STATION: KLAMATH FALLS, OREGON

FLIGHTS TO PORTLAND, OREGON

PASSENGER DATA:		
LOCAL PASSENGERS PER YEAR		16646
CONNECTING PASSENGERS PER YEAR		5272
TOTAL PASSENGERS PER YEAR		21918
TICKET PRICE		$47.00
STANDARD CLASS TICKET PRICE		$52.00
AVERAGE LOAD FACTOR - PASSENGER		49.64%
PERCENTAGE OF PASSENGER DEMAND SERVED		98.63%
MAIL AND FREIGHT DATA:		
FREIGHT PER YEAR - POUNDS		333478
FREIGHT RATE PER POUND		$0.117
PERCENTAGE OF FREIGHT DEMAND SERVED		100.00%
REVENUE (AFTER TICKET TAX):		
LOCAL TRAFFIC REVENUE		$ 719772
CONNECTING TRAFFIC REVENUE		$ 230918
FREIGHT REVENUE		$ 38978
TOTAL REVENUE		$ 989668
CONTRIBUTION		$ 65530
TRIP DISTANCE (SM)		240.0
FLIGHT RELIABILITY		97.47%
FLIGHTS INBOUND:		
LOAD FACTOR ON FLIGHT - 1	25.29%	
LOAD FACTOR ON FLIGHT - 2	51.54%	
LOAD FACTOR ON FLIGHT - 3	61.59%	
LOAD FACTOR ON FLIGHT - 4	60.32%	
FLIGHTS OUTBOUND:		
LOAD FACTOR ON FLIGHT - 1	60.80%	
LOAD FACTOR ON FLIGHT - 2	58.17%	
LOAD FACTOR ON FLIGHT - 3	62.01%	
LOAD FACTOR ON FLIGHT - 4	17.36%	

YEAR OF OPERATION: 1978

FLIGHTS TO MEDFORD, OREGON

PASSENGER DATA:		
LOCAL PASSENGERS PER YEAR		139
CONNECTING PASSENGERS PER YEAR		14370
TOTAL PASSENGERS PER YEAR		14509
TICKET PRICE		$30.00
STANDARD CLASS TICKET PRICE		$30.00
AVERAGE LOAD FACTOR - PASSENGER		29.85%
PERCENTAGE OF PASSENGER DEMAND SERVED		97.01%
MAIL AND FREIGHT DATA:		
FREIGHT PER YEAR - POUNDS		0
FREIGHT RATE PER POUND		$0.075
PERCENTAGE OF FREIGHT DEMAND SERVED		100.00%
REVENUE (AFTER TICKET TAX):		
LOCAL TRAFFIC REVENUE		$ 3820
CONNECTING TRAFFIC REVENUE		$ 458595
FREIGHT REVENUE		$ 0
TOTAL REVENUE		$ 462415
CONTRIBUTION		$ 170923
TRIP DISTANCE (SM)		61.0
FLIGHT RELIABILITY		95.92%
FLIGHTS INBOUND:		
LOAD FACTOR ON FLIGHT - 1	13.66%	
LOAD FACTOR ON FLIGHT - 2	32.33%	
LOAD FACTOR ON FLIGHT - 3	41.98%	
LOAD FACTOR ON FLIGHT - 4	29.27%	
FLIGHTS OUTBOUND:		
LOAD FACTOR ON FLIGHT - 1	31.49%	
LOAD FACTOR ON FLIGHT - 2	42.59%	
LOAD FACTOR ON FLIGHT - 3	29.82%	
LOAD FACTOR ON FLIGHT - 4	17.61%	

CONTRIBUTION OF KLAMATH FALLS, OREGON :$ 236453

TABLE 5-10 KLAMATH FALLS-1987

STATION: KLAMATH FALLS, OREGON

FLIGHTS TO PORTLAND, OREGON

PASSENGER DATA:	
LOCAL PASSENGERS PER YEAR	14459
CONNECTING PASSENGERS PER YEAR	6265
TOTAL PASSENGERS PER YEAR	20724
TICKET PRICE	$51.00
STANDARD CLASS TICKET PRICE	$52.00
AVERAGE LOAD FACTOR - PASSENGER	49.53%
PERCENTAGE OF PASSENGER DEMAND SERVED	98.45%
MAIL AND FREIGHT DATA:	
FREIGHT PER YEAR - POUNDS	400021
FREIGHT RATE PER POUND	$0.127
PERCENTAGE OF FREIGHT DEMAND SERVED	100.00%
REVENUE (AFTER TICKET TAX):	
LOCAL TRAFFIC REVENUE	$ 678396
CONNECTING TRAFFIC REVENUE	$ 283581
FREIGHT REVENUE	$ 50735
TOTAL REVENUE	$ 1012712
CONTRIBUTION	$ 5249
TRIP DISTANCE (SM)	240.0
FLIGHT RELIABILITY	97.47%
FLIGHTS INBOUND:	
LOAD FACTOR ON FLIGHT - 1	24.03%
LOAD FACTOR ON FLIGHT - 2	50.55%
LOAD FACTOR ON FLIGHT - 3	61.62%
LOAD FACTOR ON FLIGHT - 4	62.03%
FLIGHTS OUTBOUND:	
LOAD FACTOR ON FLIGHT - 1	61.69%
LOAD FACTOR ON FLIGHT - 2	58.43%
LOAD FACTOR ON FLIGHT - 3	60.54%
LOAD FACTOR ON FLIGHT - 4	17.38%

YEAR OF OPERATION: 1987

FLIGHTS TO MEDFORD, OREGON

PASSENGER DATA:	
LOCAL PASSENGERS PER YEAR	150
CONNECTING PASSENGERS PER YEAR	17096
TOTAL PASSENGERS PER YEAR	17246
TICKET PRICE	$30.00
STANDARD CLASS TICKET PRICE	$30.00
AVERAGE LOAD FACTOR - PASSENGER	37.09%
PERCENTAGE OF PASSENGER DEMAND SERVED	96.91%
MAIL AND FREIGHT DATA:	
FREIGHT PER YEAR - POUNDS	0
FREIGHT RATE PER POUND	$0.075
PERCENTAGE OF FREIGHT DEMAND SERVED	100.00%
REVENUE (AFTER TICKET TAX):	
LOCAL TRAFFIC REVENUE	$ 4136
CONNECTING TRAFFIC REVENUE	$ 545582
FREIGHT REVENUE	$ 0
TOTAL REVENUE	$ 549718
CONTRIBUTION	$ 216707
TRIP DISTANCE (SM)	61.0
FLIGHT RELIABILITY	95.92%
FLIGHTS INBOUND:	
LOAD FACTOR ON FLIGHT - 1	16.98%
LOAD FACTOR ON FLIGHT - 2	40.21%
LOAD FACTOR ON FLIGHT - 3	52.09%
LOAD FACTOR ON FLIGHT - 4	36.43%
FLIGHTS OUTBOUND:	
LOAD FACTOR ON FLIGHT - 1	39.18%
LOAD FACTOR ON FLIGHT - 2	52.86%
LOAD FACTOR ON FLIGHT - 3	37.09%
LOAD FACTOR ON FLIGHT - 4	21.90%

CONTRIBUTION OF KLAMATH FALLS, OREGON :$ 221956

TABLE 5-11 NORTH BEND-COOS BAY-1978

STATION: NORTH BEND-COOS BAY, OREGON

FLIGHTS TO PORTLAND, OREGON		
PASSENGER DATA:		
LOCAL PASSENGERS PER YEAR		17638
CONNECTING PASSENGERS PER YEAR		5976
TOTAL PASSENGERS PER YEAR		23664
TICKET PRICE		$41.00
STANDARD CLASS TICKET PRICE		$44.00
AVERAGE LOAD FACTOR - PASSENGER		52.01%
PERCENTAGE OF PASSENGER DEMAND SERVED		98.66%
MAIL AND FREIGHT DATA:		
FREIGHT PER YEAR - POUNDS		375048
FREIGHT RATE PER POUND		$0.102
PERCENTAGE OF FREIGHT DEMAND SERVED		100.00%
REVENUE (AFTER TICKET TAX):		
LOCAL TRAFFIC REVENUE		$ 667168
CONNECTING TRAFFIC REVENUE		$ 236219
FREIGHT REVENUE		$ 38241
TOTAL REVENUE		$ 941628
CONTRIBUTION		$ 217222
TRIP DISTANCE (SM)		170.0
FLIGHT RELIABILITY		96.28%
FLIGHTS INBOUND:		
LOAD FACTOR ON FLIGHT - 1	29.96%	
LOAD FACTOR ON FLIGHT - 2	52.36%	
LOAD FACTOR ON FLIGHT - 3	64.21%	
LOAD FACTOR ON FLIGHT - 4	63.39%	
FLIGHTS OUTBOUND:		
LOAD FACTOR ON FLIGHT - 1	65.53%	
LOAD FACTOR ON FLIGHT - 2	61.02%	
LOAD FACTOR ON FLIGHT - 3	64.56%	
LOAD FACTOR ON FLIGHT - 4	15.09%	

YEAR OF OPERATION: 1978

FLIGHTS TO MEDFORD, OREGON		
PASSENGER DATA:		
LOCAL PASSENGERS PER YEAR		2334
CONNECTING PASSENGERS PER YEAR		13869
TOTAL PASSENGERS PER YEAR		16203
TICKET PRICE		$35.00
STANDARD CLASS TICKET PRICE		$35.00
AVERAGE LOAD FACTOR - PASSENGER		34.48%
PERCENTAGE OF PASSENGER DEMAND SERVED		99.13%
MAIL AND FREIGHT DATA:		
FREIGHT PER YEAR - POUNDS		0
FREIGHT RATE PER POUND		$0.087
PERCENTAGE OF FREIGHT DEMAND SERVED		100.00%
REVENUE (AFTER TICKET TAX):		
LOCAL TRAFFIC REVENUE		$ 75153
CONNECTING TRAFFIC REVENUE		$ 486231
FREIGHT REVENUE		$ 0
TOTAL REVENUE		$ 561384
CONTRIBUTION		$ 161509
TRIP DISTANCE (SM)		100.0
FLIGHT RELIABILITY		95.08%
FLIGHTS INBOUND:		
LOAD FACTOR ON FLIGHT - 1	19.70%	
LOAD FACTOR ON FLIGHT - 2	37.11%	
LOAD FACTOR ON FLIGHT - 3	48.52%	
LOAD FACTOR ON FLIGHT - 4	31.24%	
FLIGHTS OUTBOUND:		
LOAD FACTOR ON FLIGHT - 1	33.62%	
LOAD FACTOR ON FLIGHT - 2	47.68%	
LOAD FACTOR ON FLIGHT - 3	36.02%	
LOAD FACTOR ON FLIGHT - 4	21.95%	

CONTRIBUTION OF NORTH BEND-COOS BAY, OREGON :$ 378731

TABLE 5-12 NORTH BEND-COOS BAY-1987

STATION: NORTH BEND-COOS BAY, OREGON

FLIGHTS TO PORTLAND, OREGON

PASSENGER DATA:		
LOCAL PASSENGERS PER YEAR		16867
CONNECTING PASSENGERS PER YEAR		6560
TOTAL PASSENGERS PER YEAR		23427
TICKET PRICE		$44.00
STANDARD CLASS TICKET PRICE		$44.00
AVERAGE LOAD FACTOR - PASSENGER		54.12%
PERCENTAGE OF PASSENGER DEMAND SERVED		98.32%
MAIL AND FREIGHT DATA:		
FREIGHT PER YEAR - POUNDS		414927
FREIGHT RATE PER POUND		$0.109
PERCENTAGE OF FREIGHT DEMAND SERVED		100.00%
REVENUE (AFTER TICKET TAX):		
LOCAL TRAFFIC REVENUE		$ 682783
CONNECTING TRAFFIC REVENUE		$ 265442
FREIGHT REVENUE		$ 45403
TOTAL REVENUE		$ 993623
CONTRIBUTION		$ 193254
TRIP DISTANCE (SM)		170.0
FLIGHT RELIABILITY		96.28%
FLIGHTS INBOUND:		
LOAD FACTOR ON FLIGHT - 1	30.57%	
LOAD FACTOR ON FLIGHT - 2	54.20%	
LOAD FACTOR ON FLIGHT - 3	66.82%	
LOAD FACTOR ON FLIGHT - 4	66.87%	
FLIGHTS OUTBOUND:		
LOAD FACTOR ON FLIGHT - 1	68.62%	
LOAD FACTOR ON FLIGHT - 2	63.63%	
LOAD FACTOR ON FLIGHT - 3	66.40%	
LOAD FACTOR ON FLIGHT - 4	15.82%	

YEAR OF OPERATION: 1987

FLIGHTS TO MEDFORD, OREGON

PASSENGER DATA:		
LOCAL PASSENGERS PER YEAR		2653
CONNECTING PASSENGERS PER YEAR		15271
TOTAL PASSENGERS PER YEAR		17924
TICKET PRICE		$35.00
STANDARD CLASS TICKET PRICE		$35.00
AVERAGE LOAD FACTOR - PASSENGER		39.93%
PERCENTAGE OF PASSENGER DEMAND SERVED		99.12%
MAIL AND FREIGHT DATA:		
FREIGHT PER YEAR - POUNDS		0
FREIGHT RATE PER POUND		$0.087
PERCENTAGE OF FREIGHT DEMAND SERVED		100.00%
REVENUE (AFTER TICKET TAX):		
LOCAL TRAFFIC REVENUE		$ 85406
CONNECTING TRAFFIC REVENUE		$ 535403
FREIGHT REVENUE		$ 0
TOTAL REVENUE		$ 620809
CONTRIBUTION		$ 168577
TRIP DISTANCE (SM)		100.0
FLIGHT RELIABILITY		95.08%
FLIGHTS INBOUND:		
LOAD FACTOR ON FLIGHT - 1	22.92%	
LOAD FACTOR ON FLIGHT - 2	42.99%	
LOAD FACTOR ON FLIGHT - 3	56.11%	
LOAD FACTOR ON FLIGHT - 4	36.11%	
FLIGHTS OUTBOUND:		
LOAD FACTOR ON FLIGHT - 1	38.96%	
LOAD FACTOR ON FLIGHT - 2	55.10%	
LOAD FACTOR ON FLIGHT - 3	41.78%	
LOAD FACTOR ON FLIGHT - 4	25.44%	

CONTRIBUTION OF NORTH BEND-COOS BAY, OREGON :$ 361831

TABLE 5-13 PENDLETON AND BAKER-LA GRANDE-1978

STATION: PENDLETON, OREGON

FLIGHTS TO PORTLAND, OREGON

PASSENGER DATA:	
LOCAL PASSENGERS PER YEAR	15418
CONNECTING PASSENGERS PER YEAR	21704
TOTAL PASSENGERS PER YEAR	37122
TICKET PRICE	$45.00
STANDARD CLASS TICKET PRICE	$45.00
AVERAGE LOAD FACTOR - PASSENGER	55.79%
PERCENTAGE OF PASSENGER DEMAND SERVED	98.01%
MAIL AND FREIGHT DATA:	
FREIGHT PER YEAR - POUNDS	447108
FREIGHT RATE PER POUND	$0.112
PERCENTAGE OF FREIGHT DEMAND SERVED	100.00%
REVENUE (AFTER TICKET TAX):	
LOCAL TRAFFIC REVENUE	$ 638299
CONNECTING TRAFFIC REVENUE	$ 902424
FREIGHT REVENUE	$ 50036
TOTAL REVENUE	$ 1590759
CONTRIBUTION	$ 452750
TRIP DISTANCE (SM)	182.0
FLIGHT RELIABILITY	97.00%
FLIGHTS INBOUND:	
LOAD FACTOR ON FLIGHT - 1	41.31%
LOAD FACTOR ON FLIGHT - 2	52.73%
LOAD FACTOR ON FLIGHT - 3	60.93%
LOAD FACTOR ON FLIGHT - 4	72.42%
LOAD FACTOR ON FLIGHT - 5	68.88%
LOAD FACTOR ON FLIGHT - 6	38.39%
FLIGHTS OUTBOUND:	
LOAD FACTOR ON FLIGHT - 1	44.05%
LOAD FACTOR ON FLIGHT - 2	70.72%
LOAD FACTOR ON FLIGHT - 3	63.08%
LOAD FACTOR ON FLIGHT - 4	59.32%
LOAD FACTOR ON FLIGHT - 5	56.06%
LOAD FACTOR ON FLIGHT - 6	41.59%

YEAR OF OPERATION: 1978

CONTRIBUTION OF PENDLETON, OREGON :$ 452750

STATION: BAKER-LA GRANDE, OREGON

FLIGHTS TO PORTLAND, OREGON

PASSENGER DATA:	
LOCAL PASSENGERS PER YEAR	10169
CONNECTING PASSENGERS PER YEAR	12899
TOTAL PASSENGERS PER YEAR	23068
TICKET PRICE	$52.00
STANDARD CLASS TICKET PRICE	$52.00
AVERAGE LOAD FACTOR - PASSENGER	52.22%
PERCENTAGE OF PASSENGER DEMAND SERVED	98.12%
MAIL AND FREIGHT DATA:	
FREIGHT PER YEAR - POUNDS	211390
FREIGHT RATE PER POUND	$0.129
PERCENTAGE OF FREIGHT DEMAND SERVED	100.00%
REVENUE (AFTER TICKET TAX):	
LOCAL TRAFFIC REVENUE	$ 486491
CONNECTING TRAFFIC REVENUE	$ 591047
FREIGHT REVENUE	$ 27336
TOTAL REVENUE	$ 1104874
CONTRIBUTION	$ 169533
TRIP DISTANCE (SM)	239.0
FLIGHT RELIABILITY	97.73%
FLIGHTS INBOUND:	
LOAD FACTOR ON FLIGHT - 1	40.18%
LOAD FACTOR ON FLIGHT - 2	53.29%
LOAD FACTOR ON FLIGHT - 3	65.66%
LOAD FACTOR ON FLIGHT - 4	48.44%
FLIGHTS OUTBOUND:	
LOAD FACTOR ON FLIGHT - 1	42.40%
LOAD FACTOR ON FLIGHT - 2	61.42%
LOAD FACTOR ON FLIGHT - 3	54.26%
LOAD FACTOR ON FLIGHT - 4	52.10%

YEAR OF OPERATION: 1978

CONTRIBUTION OF BAKER-LA GRANDE, OREGON :$ 169533

TABLE 5-14 PENDLETON AND BAKER-LA GRANDE-1987

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STATION: PENDLETON, OREGON

FLIGHTS TO PORTLAND, OREGON

PASSENGER DATA:
    LOCAL PASSENGERS PER YEAR                          18994
    CONNECTING PASSENGERS PER YEAR                     23585
    TOTAL PASSENGERS PER YEAR                          42579
    TICKET PRICE                                      $45.00
    STANDARD CLASS TICKET PRICE                       $45.00
    AVERAGE LOAD FACTOR - PASSENGER                   67.29%
    PERCENTAGE OF PASSENGER DEMAND SERVED             96.52%

MAIL AND FREIGHT DATA:
    FREIGHT PER YEAR - POUNDS                         495675
    FREIGHT RATE PER POUND                            $0.112
    PERCENTAGE OF FREIGHT DEMAND SERVED              100.00%

REVENUE (AFTER TICKET TAX):
    LOCAL TRAFFIC REVENUE                         $   786325
    CONNECTING TRAFFIC REVENUE                    $   980634
    FREIGHT REVENUE                               $    55471
    TOTAL REVENUE                                 $  1822430

CONTRIBUTION                                      $   470349

TRIP DISTANCE (SM)                                     182.0
FLIGHT RELIABILITY                                    97.00%

    FLIGHTS INBOUND:
        LOAD FACTOR ON FLIGHT - 1       51.71%
        LOAD FACTOR ON FLIGHT - 2       64.59%
        LOAD FACTOR ON FLIGHT - 3       73.54%
        LOAD FACTOR ON FLIGHT - 4       85.58%
        LOAD FACTOR ON FLIGHT - 5       81.74%
        LOAD FACTOR ON FLIGHT - 6       45.81%

    FLIGHTS OUTBOUND:
        LOAD FACTOR ON FLIGHT - 1       54.09%
        LOAD FACTOR ON FLIGHT - 2       83.33%
        LOAD FACTOR ON FLIGHT - 3       75.35%
        LOAD FACTOR ON FLIGHT - 4       71.97%
        LOAD FACTOR ON FLIGHT - 5       68.82%
        LOAD FACTOR ON FLIGHT - 6       50.90%

YEAR OF OPERATION:  1987

CONTRIBUTION OF PENDLETON, OREGON               :$  470349
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STATION: BAKER-LA GRANDE, OREGON

FLIGHTS TO PORTLAND, OREGON

PASSENGER DATA:
    LOCAL PASSENGERS PER YEAR                          11009
    CONNECTING PASSENGERS PER YEAR                     13766
    TOTAL PASSENGERS PER YEAR                          24775
    TICKET PRICE                                      $52.00
    STANDARD CLASS TICKET PRICE                       $52.00
    AVERAGE LOAD FACTOR - PASSENGER                   59.19%
    PERCENTAGE OF PASSENGER DEMAND SERVED             97.41%

MAIL AND FREIGHT DATA:
    FREIGHT PER YEAR - POUNDS                         227975
    FREIGHT RATE PER POUND                            $0.129
    PERCENTAGE OF FREIGHT DEMAND SERVED              100.00%

REVENUE (AFTER TICKET TAX):
    LOCAL TRAFFIC REVENUE                         $   526626
    CONNECTING TRAFFIC REVENUE                    $   630781
    FREIGHT REVENUE                               $    29481
    TOTAL REVENUE                                 $  1186888

CONTRIBUTION                                      $   110852

TRIP DISTANCE (SM)                                     239.0
FLIGHT RELIABILITY                                    97.73%

    FLIGHTS INBOUND:
        LOAD FACTOR ON FLIGHT - 1       45.93%
        LOAD FACTOR ON FLIGHT - 2       60.52%
        LOAD FACTOR ON FLIGHT - 3       73.62%
        LOAD FACTOR ON FLIGHT - 4       55.06%

    FLIGHTS OUTBOUND:
        LOAD FACTOR ON FLIGHT - 1       48.38%
        LOAD FACTOR ON FLIGHT - 2       69.19%
        LOAD FACTOR ON FLIGHT - 3       61.60%
        LOAD FACTOR ON FLIGHT - 4       59.25%

YEAR OF OPERATION:  1987

CONTRIBUTION OF BAKER-LA GRANDE, OREGON         :$  110852
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TABLE 5-15 REDMOND-BEND-1978

STATION: REDMOND-BEND, OREGON

FLIGHTS TO PORTLAND, OREGON		FLIGHTS TO MEDFORD, OREGON	
PASSENGER DATA:		**PASSENGER DATA:**	
LOCAL PASSENGERS PER YEAR	9892	LOCAL PASSENGERS PER YEAR	1563
CONNECTING PASSENGERS PER YEAR	5079	CONNECTING PASSENGERS PER YEAR	12545
TOTAL PASSENGERS PER YEAR	14971	TOTAL PASSENGERS PER YEAR	14108
TICKET PRICE	$37.00	TICKET PRICE	$42.00
STANDARD CLASS TICKET PRICE	$37.00	STANDARD CLASS TICKET PRICE	$42.00
AVERAGE LOAD FACTOR - PASSENGER	31.59%	AVERAGE LOAD FACTOR - PASSENGER	31.13%
PERCENTAGE OF PASSENGER DEMAND SERVED	87.52%	PERCENTAGE OF PASSENGER DEMAND SERVED	94.00%
MAIL AND FREIGHT DATA:		**MAIL AND FREIGHT DATA:**	
FREIGHT PER YEAR - POUNDS	432165	FREIGHT PER YEAR - POUNDS	0
FREIGHT RATE PER POUND	$0.092	FREIGHT RATE PER POUND	$0.104
PERCENTAGE OF FREIGHT DEMAND SERVED	100.00%	PERCENTAGE OF FREIGHT DEMAND SERVED	100.00%
REVENUE (AFTER TICKET TAX):		**REVENUE (AFTER TICKET TAX):**	
LOCAL TRAFFIC REVENUE	$ 336730	LOCAL TRAFFIC REVENUE	$ 60388
CONNECTING TRAFFIC REVENUE	$ 185696	CONNECTING TRAFFIC REVENUE	$ 496440
FREIGHT REVENUE	$ 39766	FREIGHT REVENUE	$ 0
TOTAL REVENUE	$ 562192	TOTAL REVENUE	$ 556828
CONTRIBUTION	$ 85087	CONTRIBUTION	$ 1792
TRIP DISTANCE (SM)	116.0	TRIP DISTANCE (SM)	156.0
FLIGHT RELIABILITY	97.86%	FLIGHT RELIABILITY	96.24%
FLIGHTS INBOUND:		**FLIGHTS INBOUND:**	
LOAD FACTOR ON FLIGHT - 1	14.80%	LOAD FACTOR ON FLIGHT - 1	15.82%
LOAD FACTOR ON FLIGHT - 2	31.04%	LOAD FACTOR ON FLIGHT - 2	33.70%
LOAD FACTOR ON FLIGHT - 3	39.25%	LOAD FACTOR ON FLIGHT - 3	43.85%
LOAD FACTOR ON FLIGHT - 4	40.93%	LOAD FACTOR ON FLIGHT - 4	28.92%
FLIGHTS OUTBOUND:		**FLIGHTS OUTBOUND:**	
LOAD FACTOR ON FLIGHT - 1	43.14%	LOAD FACTOR ON FLIGHT - 1	26.11%
LOAD FACTOR ON FLIGHT - 2	37.82%	LOAD FACTOR ON FLIGHT - 2	44.73%
LOAD FACTOR ON FLIGHT - 3	38.58%	LOAD FACTOR ON FLIGHT - 3	33.30%
LOAD FACTOR ON FLIGHT - 4	7.14%	LOAD FACTOR ON FLIGHT - 4	22.64%

YEAR OF OPERATION: 1978

CONTRIBUTION OF REDMOND-BEND, OREGON :$ 86879

TABLE 5-16 REDMOND-BEND-1987

STATION: REDMOND-BEND, OREGON

FLIGHTS TO PORTLAND, OREGON

PASSENGER DATA:		
LOCAL PASSENGERS PER YEAR		10502
CONNECTING PASSENGERS PER YEAR		6198
TOTAL PASSENGERS PER YEAR		16700
TICKET PRICE		$37.00
STANDARD CLASS TICKET PRICE		$37.00
AVERAGE LOAD FACTOR - PASSENGER		36.95%
PERCENTAGE OF PASSENGER DEMAND SERVED		87.30%
MAIL AND FREIGHT DATA:		
FREIGHT PER YEAR - POUNDS		533291
FREIGHT RATE PER POUND		$0.092
PERCENTAGE OF FREIGHT DEMAND SERVED		100.00%
REVENUE (AFTER TICKET TAX):		
LOCAL TRAFFIC REVENUE		$ 357496
CONNECTING TRAFFIC REVENUE		$ 226614
FREIGHT REVENUE		$ 49071
TOTAL REVENUE		$ 633181
CONTRIBUTION		$ 85587
TRIP DISTANCE (SM)		116.0
FLIGHT RELIABILITY		97.86%
FLIGHTS INBOUND:		
LOAD FACTOR ON FLIGHT - 1	16.86%	
LOAD FACTOR ON FLIGHT - 2	36.03%	
LOAD FACTOR ON FLIGHT - 3	46.00%	
LOAD FACTOR ON FLIGHT - 4	48.56%	
FLIGHTS OUTBOUND:		
LOAD FACTOR ON FLIGHT - 1	50.88%	
LOAD FACTOR ON FLIGHT - 2	44.30%	
LOAD FACTOR ON FLIGHT - 3	44.49%	
LOAD FACTOR ON FLIGHT - 4	8.49%	

YEAR OF OPERATION: 1987

FLIGHTS TO MEDFORD, OREGON

PASSENGER DATA:		
LOCAL PASSENGERS PER YEAR		1708
CONNECTING PASSENGERS PER YEAR		15270
TOTAL PASSENGERS PER YEAR		16978
TICKET PRICE		$42.00
STANDARD CLASS TICKET PRICE		$42.00
AVERAGE LOAD FACTOR - PASSENGER		39.40%
PERCENTAGE OF PASSENGER DEMAND SERVED		93.50%
MAIL AND FREIGHT DATA:		
FREIGHT PER YEAR - POUNDS		0
FREIGHT RATE PER POUND		$0.104
PERCENTAGE OF FREIGHT DEMAND SERVED		100.00%
REVENUE (AFTER TICKET TAX):		
LOCAL TRAFFIC REVENUE		$ 65999
CONNECTING TRAFFIC REVENUE		$ 604270
FREIGHT REVENUE		$ 0
TOTAL REVENUE		$ 670269
CONTRIBUTION		$ 18456
TRIP DISTANCE (SM)		156.0
FLIGHT RELIABILITY		96.24%
FLIGHTS INBOUND:		
LOAD FACTOR ON FLIGHT - 1	19.88%	
LOAD FACTOR ON FLIGHT - 2	42.76%	
LOAD FACTOR ON FLIGHT - 3	55.12%	
LOAD FACTOR ON FLIGHT - 4	36.98%	
FLIGHTS OUTBOUND:		
LOAD FACTOR ON FLIGHT - 1	33.17%	
LOAD FACTOR ON FLIGHT - 2	56.38%	
LOAD FACTOR ON FLIGHT - 3	42.17%	
LOAD FACTOR ON FLIGHT - 4	28.75%	

CONTRIBUTION OF REDMOND-BEND, OREGON :$ 104043

TABLE 5-17 ROSEBURG-1978

STATION: ROSEBURG, OREGON

FLIGHTS TO PORTLAND, OREGON

PASSENGER DATA:		
LOCAL PASSENGERS PER YEAR		6980
CONNECTING PASSENGERS PER YEAR		5621
TOTAL PASSENGERS PER YEAR		12601
TICKET PRICE		$43.00
STANDARD CLASS TICKET PRICE		$43.00
AVERAGE LOAD FACTOR - PASSENGER		28.47%
PERCENTAGE OF PASSENGER DEMAND SERVED		99.88%
MAIL AND FREIGHT DATA:		
FREIGHT PER YEAR - POUNDS		415859
FREIGHT RATE PER POUND		$0.107
PERCENTAGE OF FREIGHT DEMAND SERVED		100.00%
REVENUE (AFTER TICKET TAX):		
LOCAL TRAFFIC REVENUE		$ 276146
CONNECTING TRAFFIC REVENUE		$ 223495
FREIGHT REVENUE		$ 44470
TOTAL REVENUE		$ 544111
CONTRIBUTION		$ -1667
TRIP DISTANCE (SM)		167.0
FLIGHT RELIABILITY		92.61%
FLIGHTS INBOUND:		
LOAD FACTOR ON FLIGHT - 1	16.84%	
LOAD FACTOR ON FLIGHT - 2	29.06%	
LOAD FACTOR ON FLIGHT - 3	35.50%	
LOAD FACTOR ON FLIGHT - 4	37.09%	
FLIGHTS OUTBOUND:		
LOAD FACTOR ON FLIGHT - 1	37.01%	
LOAD FACTOR ON FLIGHT - 2	32.48%	
LOAD FACTOR ON FLIGHT - 3	32.08%	
LOAD FACTOR ON FLIGHT - 4	7.66%	

YEAR OF OPERATION: 1978

FLIGHTS TO MEDFORD, OREGON

PASSENGER DATA:		
LOCAL PASSENGERS PER YEAR		253
CONNECTING PASSENGERS PER YEAR		12765
TOTAL PASSENGERS PER YEAR		13018
TICKET PRICE		$31.00
STANDARD CLASS TICKET PRICE		$31.00
AVERAGE LOAD FACTOR - PASSENGER		27.78%
PERCENTAGE OF PASSENGER DEMAND SERVED		98.55%
MAIL AND FREIGHT DATA:		
FREIGHT PER YEAR - POUNDS		0
FREIGHT RATE PER POUND		$0.077
PERCENTAGE OF FREIGHT DEMAND SERVED		100.00%
REVENUE (AFTER TICKET TAX):		
LOCAL TRAFFIC REVENUE		$ 7214
CONNECTING TRAFFIC REVENUE		$ 411792
FREIGHT REVENUE		$ 0
TOTAL REVENUE		$ 419006
CONTRIBUTION		$ 142992
TRIP DISTANCE (SM)		65.0
FLIGHT RELIABILITY		91.57%
FLIGHTS INBOUND:		
LOAD FACTOR ON FLIGHT - 1	17.05%	
LOAD FACTOR ON FLIGHT - 2	32.05%	
LOAD FACTOR ON FLIGHT - 3	39.21%	
LOAD FACTOR ON FLIGHT - 4	25.65%	
FLIGHTS OUTBOUND:		
LOAD FACTOR ON FLIGHT - 1	26.73%	
LOAD FACTOR ON FLIGHT - 2	37.99%	
LOAD FACTOR ON FLIGHT - 3	27.10%	
LOAD FACTOR ON FLIGHT - 4	16.43%	

CONTRIBUTION OF ROSEBURG, OREGON :$ 141325

TABLE 5-18 ROSEBURG-1987

STATION: ROSEBURG, OREGON

FLIGHTS TO PORTLAND, OREGON

PASSENGER DATA:	
LOCAL PASSENGERS PER YEAR	7514
CONNECTING PASSENGERS PER YEAR	6377
TOTAL PASSENGERS PER YEAR	13891
TICKET PRICE	$43.00
STANDARD CLASS TICKET PRICE	$43.00
AVERAGE LOAD FACTOR - PASSENGER	32.95%
PERCENTAGE OF PASSENGER DEMAND SERVED	99.86%
MAIL AND FREIGHT DATA:	
FREIGHT PER YEAR - POUNDS	474354
FREIGHT RATE PER POUND	$0.107
PERCENTAGE OF FREIGHT DEMAND SERVED	100.00%
REVENUE (AFTER TICKET TAX):	
LOCAL TRAFFIC REVENUE	$ 297255
CONNECTING TRAFFIC REVENUE	$ 253547
FREIGHT REVENUE	$ 50726
TOTAL REVENUE	$ 601528
CONTRIBUTION	$ -23311
TRIP DISTANCE (SM)	167.0
FLIGHT RELIABILITY	92.61%

FLIGHTS INBOUND:	
LOAD FACTOR ON FLIGHT - 1	19.25%
LOAD FACTOR ON FLIGHT - 2	33.55%
LOAD FACTOR ON FLIGHT - 3	41.14%
LOAD FACTOR ON FLIGHT - 4	43.21%
FLIGHTS OUTBOUND:	
LOAD FACTOR ON FLIGHT - 1	42.99%
LOAD FACTOR ON FLIGHT - 2	37.65%
LOAD FACTOR ON FLIGHT - 3	36.93%
LOAD FACTOR ON FLIGHT - 4	8.90%

YEAR OF OPERATION: 1987

FLIGHTS TO MEDFORD, OREGON

PASSENGER DATA:	
LOCAL PASSENGERS PER YEAR	281
CONNECTING PASSENGERS PER YEAR	14480
TOTAL PASSENGERS PER YEAR	14761
TICKET PRICE	$31.00
STANDARD CLASS TICKET PRICE	$31.00
AVERAGE LOAD FACTOR - PASSENGER	32.93%
PERCENTAGE OF PASSENGER DEMAND SERVED	98.52%
MAIL AND FREIGHT DATA:	
FREIGHT PER YEAR - POUNDS	0
FREIGHT RATE PER POUND	$0.077
PERCENTAGE OF FREIGHT DEMAND SERVED	100.00%
REVENUE (AFTER TICKET TAX):	
LOCAL TRAFFIC REVENUE	$ 8012
CONNECTING TRAFFIC REVENUE	$ 467136
FREIGHT REVENUE	$ 0
TOTAL REVENUE	$ 475148
CONTRIBUTION	$ 163671
TRIP DISTANCE (SM)	65.0
FLIGHT RELIABILITY	91.57%

FLIGHTS INBOUND:	
LOAD FACTOR ON FLIGHT - 1	20.21%
LOAD FACTOR ON FLIGHT - 2	38.00%
LOAD FACTOR ON FLIGHT - 3	46.47%
LOAD FACTOR ON FLIGHT - 4	30.42%
FLIGHTS OUTBOUND:	
LOAD FACTOR ON FLIGHT - 1	31.70%
LOAD FACTOR ON FLIGHT - 2	45.02%
LOAD FACTOR ON FLIGHT - 3	32.13%
LOAD FACTOR ON FLIGHT - 4	19.48%

CONTRIBUTION OF ROSEBURG, OREGON :$ 140360

TABLE 5-19 SALEM-1978

STATION: SALEM, OREGON

FLIGHTS TO PORTLAND, OREGON

PASSENGER DATA:		
LOCAL PASSENGERS PER YEAR		2550
CONNECTING PASSENGERS PER YEAR		6502
TOTAL PASSENGERS PER YEAR		9052
TICKET PRICE		$29.00
STANDARD CLASS TICKET PRICE		$29.00
AVERAGE LOAD FACTOR - PASSENGER		18.31%
PERCENTAGE OF PASSENGER DEMAND SERVED		97.02%
MAIL AND FREIGHT DATA:		
FREIGHT PER YEAR - POUNDS		1215088
FREIGHT RATE PER POUND		$0.072
PERCENTAGE OF FREIGHT DEMAND SERVED		100.00%
REVENUE (AFTER TICKET TAX):		
LOCAL TRAFFIC REVENUE		$ 68053
CONNECTING TRAFFIC REVENUE		$ 202558
FREIGHT REVENUE		$ 87632
TOTAL REVENUE		$ 358243
CONTRIBUTION		$ 85395
TRIP DISTANCE (SM)		51.0
FLIGHT RELIABILITY		96.86%
FLIGHTS INBOUND:		
LOAD FACTOR ON FLIGHT - 1	6.60%	
LOAD FACTOR ON FLIGHT - 2	16.53%	
LOAD FACTOR ON FLIGHT - 3	23.21%	
LOAD FACTOR ON FLIGHT - 4	27.02%	
FLIGHTS OUTBOUND:		
LOAD FACTOR ON FLIGHT - 1	28.90%	
LOAD FACTOR ON FLIGHT - 2	21.90%	
LOAD FACTOR ON FLIGHT - 3	18.07%	
LOAD FACTOR ON FLIGHT - 4	4.21%	

YEAR OF OPERATION: 1978

FLIGHTS TO MEDFORD, OREGON

PASSENGER DATA:		
LOCAL PASSENGERS PER YEAR		3960
CONNECTING PASSENGERS PER YEAR		18101
TOTAL PASSENGERS PER YEAR		22061
TICKET PRICE		$44.00
STANDARD CLASS TICKET PRICE		$44.00
AVERAGE LOAD FACTOR - PASSENGER		48.67%
PERCENTAGE OF PASSENGER DEMAND SERVED		99.33%
MAIL AND FREIGHT DATA:		
FREIGHT PER YEAR - POUNDS		0
FREIGHT RATE PER POUND		$0.109
PERCENTAGE OF FREIGHT DEMAND SERVED		100.00%
REVENUE (AFTER TICKET TAX):		
LOCAL TRAFFIC REVENUE		$ 160315
CONNECTING TRAFFIC REVENUE		$ 730776
FREIGHT REVENUE		$ 0
TOTAL REVENUE		$ 891091
CONTRIBUTION		$ 221307
TRIP DISTANCE (SM)		175.0
FLIGHT RELIABILITY		95.49%
FLIGHTS INBOUND:		
LOAD FACTOR ON FLIGHT - 1	29.80%	
LOAD FACTOR ON FLIGHT - 2	53.36%	
LOAD FACTOR ON FLIGHT - 3	67.97%	
LOAD FACTOR ON FLIGHT - 4	41.03%	
FLIGHTS OUTBOUND:		
LOAD FACTOR ON FLIGHT - 1	40.90%	
LOAD FACTOR ON FLIGHT - 2	67.79%	
LOAD FACTOR ON FLIGHT - 3	52.71%	
LOAD FACTOR ON FLIGHT - 4	35.80%	

CONTRIBUTION OF SALEM, OREGON :$ 306702

TABLE 5-20 SALEM-1987

STATION: SALEM, OREGON

FLIGHTS TO PORTLAND, OREGON

PASSENGER DATA:	
LOCAL PASSENGERS PER YEAR	3002
CONNECTING PASSENGERS PER YEAR	7533
TOTAL PASSENGERS PER YEAR	10535
TICKET PRICE	$29.00
STANDARD CLASS TICKET PRICE	$29.00
AVERAGE LOAD FACTOR - PASSENGER	22.27%
PERCENTAGE OF PASSENGER DEMAND SERVED	97.02%
MAIL AND FREIGHT DATA:	
FREIGHT PER YEAR - POUNDS	1416447
FREIGHT RATE PER POUND	$0.072
PERCENTAGE OF FREIGHT DEMAND SERVED	100.00%
REVENUE (AFTER TICKET TAX):	
LOCAL TRAFFIC REVENUE	$ 80097
CONNECTING TRAFFIC REVENUE	$ 234681
FREIGHT REVENUE	$ 102154
TOTAL REVENUE	$ 416932
CONTRIBUTION	$ 107423
TRIP DISTANCE (SM)	51.0
FLIGHT RELIABILITY	96.86%
FLIGHTS INBOUND:	
LOAD FACTOR ON FLIGHT - 1	8.07%
LOAD FACTOR ON FLIGHT - 2	20.12%
LOAD FACTOR ON FLIGHT - 3	28.23%
LOAD FACTOR ON FLIGHT - 4	32.83%
FLIGHTS OUTBOUND:	
LOAD FACTOR ON FLIGHT - 1	35.12%
LOAD FACTOR ON FLIGHT - 2	26.64%
LOAD FACTOR ON FLIGHT - 3	22.02%
LOAD FACTOR ON FLIGHT - 4	5.11%

YEAR OF OPERATION: 1987

FLIGHTS TO MEDFORD, OREGON

PASSENGER DATA:	
LOCAL PASSENGERS PER YEAR	4744
CONNECTING PASSENGERS PER YEAR	20648
TOTAL PASSENGERS PER YEAR	25392
TICKET PRICE	$44.00
STANDARD CLASS TICKET PRICE	$44.00
AVERAGE LOAD FACTOR - PASSENGER	58.86%
PERCENTAGE OF PASSENGER DEMAND SERVED	97.83%
MAIL AND FREIGHT DATA:	
FREIGHT PER YEAR - POUNDS	0
FREIGHT RATE PER POUND	$0.109
PERCENTAGE OF FREIGHT DEMAND SERVED	100.00%
REVENUE (AFTER TICKET TAX):	
LOCAL TRAFFIC REVENUE	$ 192030
CONNECTING TRAFFIC REVENUE	$ 833621
FREIGHT REVENUE	$ 0
TOTAL REVENUE	$ 1025651
CONTRIBUTION	$ 233790
TRIP DISTANCE (SM)	175.0
FLIGHT RELIABILITY	95.49%
FLIGHTS INBOUND:	
LOAD FACTOR ON FLIGHT - 1	36.85%
LOAD FACTOR ON FLIGHT - 2	64.81%
LOAD FACTOR ON FLIGHT - 3	80.41%
LOAD FACTOR ON FLIGHT - 4	50.07%
FLIGHTS OUTBOUND:	
LOAD FACTOR ON FLIGHT - 1	50.21%
LOAD FACTOR ON FLIGHT - 2	80.35%
LOAD FACTOR ON FLIGHT - 3	64.22%
LOAD FACTOR ON FLIGHT - 4	43.98%

CONTRIBUTION OF SALEM, OREGON :$ 341213

The average load factor is the average of all inbound and outbound flights based on available seats (payload (pounds)/191 (pounds per passenger)).

The percentage of passenger demand served (PDS) is the complement of the percentage of passengers refused (100-PDS) because of unavailable seats, i.e., payload. It is not a function of mechanical reliabilty or meteorology.

The air freight per year is self-explanatory. The air freight rate per pound is given by:

$$\text{Max}\left\{\frac{0.475\ F}{PW},\ \frac{CPM\ D}{PW}\right\}$$

where

F is the passenger fare,

CPM is the marginal cost per revenue-passenger-mile (IOC costs plus pilot and mechanic RPM component) of $0.07941 in 1978 and $0.08899 in 1985, both in 1978 dollars,

D is the route distance (sm), and

PW is the mean passenger weight (191 pounds).

The percentage of air freight demand served is always 100% because of the unused payload capacity throughout the day.

The revenue after ticket tax is the total revenue minus 8% for passengers and minus 5% for air freight except that the variable cost per pound-mile for air freight is always recovered.

The total revenue is the sum of the passenger after-tax revenues and air freight after-tax revenue.

The contribution is the result of maximizing the objective function. If the route contribution is subtracted from the route total revenue the route variable costs are obtained.

The trip distance is self-explanatory.

The flight reliability is mechanical reliability multiplied by the average of the station's meteorological completion factor upon arrival weighted by passengers per flight, and the average of either Portland or Medford's meteorological completion factor upon arrival weighted by passengers per flight.

The load factors for flights inbound (from Portland or Medford) and for flights outbound (to Portland or Medford) are based on available seats.

The year of operation is self-explanatory.

The contribution of the station is the contribution of all routes through the station. It is the output of the objective function and is used to decide whether or not the station is offered service.

5.4.2 Annual Statistics

The airline's annual statistics for years 1978 and 1987 are given in Tables 5-21 and 5-22. Most of the statistics are cumulative totals or weighted averages of the station statistics. The tables are explained below.

The connecting traffic is 62.84% in 1978 and 64.54% in 1985 of the total traffic. Third-level airline traffic is normally 60-70% connecting, so the results are in the expected range.[40]

Passenger traffic growth between 1978 and 1987 in Oregon is 10.63% or 1.02% per year. This is low, but there are no changes in equipment or quality of service and aircraft weight growth causes available seats per departure to decrease by 4.7%. Real fares increase by 2.36% and PIM (Section 2.5) decreases because of the more uniform interpersonal distribution of taxable income. Growth in the period is less for intra-Oregon traffic (5.6%) than for connecting traffic (13.6%). Air freight increases 16.8% in the period because it is assumed price inelastic, and because it is unaffected by available seats per departure.

The mean ticket price in 1978 is $43.18 for which the elasticity is -2.01 and in 1987 is $44.20 for which the elasticity is -2.06, both in 1978 dollars.

Dilution of connecting traffic revenue because of joint fares is 4.1% in 1978 and 6.3% in 1987. Third-level airlines normally experience about 15% dilution.[17] The reason for the difference is that most negotiated joint-fare agreements are not as favorable to third-level airlines as DPFI phase 4, which was assumed in this study.

Air freight constitutes 3.8% of revenue in 1978 and 3.9% of revenue in 1987. This may be compared to the results of a survey of ten third-level airlines given in Table 5-23. The percentages are within the range, but below the mean.

The average load factor of the airline is 37.07% in 1978 and 43.03% in 1987; these percentages are based on the average available seats per departure of 17.70 in 1978 and 16.86 in 1987. Based on the nineteen installed seats, the load factors are 34.53% in 1978 and 38.21% in 1987. One study listed five third-level airlines with unspecified route systems with load factors ranging from 33.6% to 57.0% and averaging 42.1%.[10] The present study found three third-level airlines with linear route systems with load factors of 53.1%, 46.1%, and 48%, for an average of 49.1%. And, one airline with a hub-and-spoke route system with a load factor of 33%. The four-airline average is 45%.

The airline in Oregon has a double hub-and-spoke route system. It is usually difficult to get load factors over 50% on a hub-and-spoke route system. First, there is a high degree of peaking and directionality. Second, if the system has multi-stop spokes (not applicable in Oregon) the aircraft must be sized large enough to accumulate traffic

TABLE 5-21

AIRLINE ANNUAL STATISTICS - 1978

ANNUAL DEMAND SERVED:

LOCAL PASSENGERS PER YEAR		91679
TOTAL CONNECTING PASSENGERS PER YEAR		155063
TOTAL PASSENGERS SERVED PER YEAR		246742
PERCENTAGE OF PASSENGER DEMAND SERVED		97.50%
TOTAL FREIGHT PER YEAR - POUNDS		4173871.
PERCENTAGE OF FREIGHT DEMAND SERVED		100.00%

REVENUE (AFTER TICKET TAX):

ANNUAL REVENUE FROM LOCAL TRAFFIC	$	3642491.
ANNUAL REVENUE FROM CONNECTING TRAFFIC	$	5908757.
ANNUAL REVENUE FROM MAIL AND FREIGHT	$	387499.
TOTAL ANNUAL REVENUE	$	9938748.
TOTAL ANNUAL VARIABLE COSTS	$	8074844.
ANNUAL AIRLINE CONTRIBUTION	$	1863904.

AIRLINE AVERAGE LOAD FACTOR	37.07%
TOTAL REVENUE PASSENGER MILES PER YEAR	38411707.
TOTAL REVENUE TON MILES PER YEAR	3927802.
% OF REVENUE TON MILES IN FREIGHT	6.61%
TOTAL DEPARTURES PER YEAR	37604
SCHEDULED DEPARTURES PER YEAR	39238
% OF SCHEDULED DEPARTURES PERFORMED	95.84%
FLIGHT HOURS PER YEAR	26589.
REVENUE MILES FLOWN	5854055.
AVAILABLE SEAT MILES	103632628.
AVAILABLE TON MILES	9896916.
AVAILABLE SEAT DEPARTURES	665698

YIELD PER PASSENGER MILE	$0.249
YIELD PER TON MILE - FREIGHT	$1.493
VARIABLE COST PER REVENUE PASSENGER MILE	$0.210
VARIABLE COST PER REVENUE TON MILE	$2.056
VARIABLE COST PER AVAILABLE SEAT MILE	$0.078
VARIABLE COST PER AVAILABLE TON MILE	$0.316

TABLE 5-21

AIRLINE ANNUAL STATISTICS - 1987

ANNUAL DEMAND SERVED:

LOCAL PASSENGERS PER YEAR		96846
TOTAL CONNECTING PASSENGERS PER YEAR		176124
TOTAL PASSENGERS SERVED PER YEAR		272970
PERCENTAGE OF PASSENGER DEMAND SERVED		96.90%
TOTAL FREIGHT PER YEAR - POUNDS		4812082.
PERCENTAGE OF FREIGHT DEMAND SERVED		100.00%

REVENUE (AFTER TICKET TAX):

ANNUAL REVENUE FROM LOCAL TRAFFIC	$	3938452.
ANNUAL REVENUE FROM CONNECTING TRAFFIC	$	6714093.
ANNUAL REVENUE FROM MAIL AND FREIGHT	$	452752.
TOTAL ANNUAL REVENUE	$	11105298.
TOTAL ANNUAL VARIABLE COSTS	$	9251847.
ANNUAL AIRLINE CONTRIBUTION	$	1853450.

AIRLINE AVERAGE LOAD FACTOR	43.03%
TOTAL REVENUE PASSENGER MILES PER YEAR	41921527.
TOTAL REVENUE TON MILES PER YEAR	4301035.
% OF REVENUE TON MILES IN FREIGHT	6.92%
TOTAL DEPARTURES PER YEAR	37604
SCHEDULED DEPARTURES PER YEAR	39238
% OF SCHEDULED DEPARTURES PERFORMED	95.84%
FLIGHT HOURS PER YEAR	27543.
REVENUE MILES FLOWN	5854055.
AVAILABLE SEAT MILES	97415483.
AVAILABLE TON MILES	9303179.
AVAILABLE SEAT DEPARTURES	634316

YIELD PER PASSENGER MILE	$0.254
YIELD PER TON MILE - FREIGHT	$1.522
VARIABLE COST PER REVENUE PASSENGER MILE	$0.221
VARIABLE COST PER REVENUE TON MILE	$2.151
VARIABLE COST PER AVAILABLE SEAT MILE	$0.095
VARIABLE COST PER AVAILABLE TON MILE	$0.994

TABLE 5-23

DISTRIBUTION OF FIFTEEN THIRD-LEVEL AIRLINE OPERATING REVENUES[9]
(Excluding subsidy and other operations)

Revenue Source	Average %	Percent Range
Scheduled Passenger	90.0	78.3 - 98.4
Charter	4.1	0.3 - 20.2
Freight	4.6	0.3 - 11.2
Mail[1]	3.0	2.2 - 4.4
Baggage	0.1	0.1 - 2.0
Miscellaneous	0.3	0.2 - 4.0

1 Three operators only

at the stops on the way to the hub. When it is far from the hub it will have low load factors. As the aircraft flys towards the hub, the effective seating capacity of the aircraft decreases. This causes passengers in the most reliability-sensitive markets to be refused seats most often, but if extra seats (larger aircraft) are made available they compound the load factor problem (Section 5.3.3.2.1). In contrast, linear route systems feed themselves, and load factors can approach 60%.

The total revenue-passenger-miles per year are passenger miles only. Total revenue-ton-miles per year modified by 10.4712 (2000 pounds/191 pounds per passenger) is used for revenue-passenger-miles in the regression equations.

The difference between 1978 and 1987 flight-hours, available-seat-miles, available-ton-miles, and available-seat-departures results from aircraft performance degradation.

5.4.3 Computed Airline Statistics

The results of the final iteration for the most-likely levels of demand (revenue) and costs, and their respective modifications over the 1978 to 1987 time period, in 1978 dollars, are given in Table 5-24.

The marginal cost per RPM includes both indirect operating costs per mile and that portion of pilot and mechanic salaries that are RPM dependent. The RPMs include air freight at 191 pound-miles per passenger-mile.

The direct and indirect operating costs are an outgrowth of the formulae and assumptions in Section 3. IOCs are increasing as a percentage of total cost over the period. The reason is that labor is only 30% of DOCs, but 60% of IOCs and the cost of labor is increasing in real terms. IOCs are normally a larger percentage of total costs, but taxes and depreciation of ground property, which are normally included, are not included.

5.4.4 Comparison with Data Base Airlines

The published data of the airlines forming the data base for the year ending 31 December 1977 along with the data for a mature operation in Oregon are given in Table 5-25. The airline in Oregon would rank second among the data base airlines for revenue-passenger-miles, and air freight and airmail in both tons and ton-miles. It would rank fourth among the data base airlines for passengers boarded. It is important that the airline statistics be within the data base. It was within the proprietory statistics of the data base airlines as well, e.g., revenue, indirect operating costs--labor, and indirect operating costs--nonlabor. Additionally, the Oregon airline would rank fourth nationally in revenue-passenger-miles and seventh nationally in passengers boarded.

5.4.5 Comparison with U. S. Third-level Markets

The Oregon market statistics are compared against third-level airline markets nationwide in terms of third-level journey length and passengers per day in the market (Table 5-26). The Oregon markets have

TABLE 5-24

1978 AND 1987 COMPUTED AIRLINE STATISTICS
(1978 Dollars)

STATISTICS	1978*	1987
GENERAL		
Marginal Cost Per RPM	$0.07941	$0.08899
RPMs (Including Airmail & Air Freight)	41128817	45037016
EMPLOYEES		
Indirect	175	192
Pilots	56	58
Mechanics	20	21
Total Employees	251	271
DIRECT OPERATING COSTS		
Aircraft	1236367	1236367
Fuel	1273659	1584331
Oil	6191	7701
Crew	960354	1214815
Engineering Labor	335301	357315
Avionics Labor	26401	26524
Maintenance Burden	261535	278706
Aircraft Material	457431	475485
Avionics Material	9253	9585
Engines	731463	757708
Insurance	190057	158381
Total DOCs	5488012(68%)	6106918(66%)
INDIRECT OPERATING COSTS		
Labor	1519112	1985924
Nonlabor**	1067720	1159005
Total IOCs	2586832(32%)	3144929(34%)
TOTAL COST**	8074844(100%)	9251847(100%)

Traffic and Reliability Build Ups Not Included

Exclusive of Corporate Excise Tax

TABLE 5-25

COMPARISON OF OREGON AIRLINE AGAINST DATA BASE AIRLINES*

	Passengers	Revenue Passenger Miles	Air Freight and Airmail (lbs)[5]	Air Freight and Airmail (Ton-Miles)[5]
Air Wisconsin[1]	324581(4)	47843682(2)	4526047	320171
Metro Airlines[2]	304413(5)	24241861(12)	868314	37966
Pilgrim Aviation[3]	139944(20)	15448187(20)	1462404	53234
Rio Airways[4]	244823(7)	28126043(7)	---	---
Oregon Airline	246742(7)	38411707(4)	4173768	259628

* December 31, 1977 Annual Statistics Of Air Wisconsin, Metro Airlines, Pilgrim Aviation and Rio Airways

( ) Civil Aeronautics Board ranking

1 Air freight only, not reported in top 50 for airmail

2 Air freight and airmail

3 Airmail only, not reported as not in Top 50 for air freight

4 Not reported as not in Top 50 for either air freight or airmail

5 Because of the combining of air freight and airmail no CAB ranking is available.

TABLE 5-26

DISTRIBUTION OF THIRD-LEVEL PASSENGER MARKETS
BY MILEAGE AND PASSENGERS PER DAY[4]
12 Months Ended December 31, 1977

Nonstop Mileage	Number of Markets By Passengers Per Day 0.0-0.9	1.0-9.9	10.0-19.9	20.0-29.9	30.0-39.9	40.0 or more	Total
0-24	47	15	1	2	1	2	68
25-49	95	29	12	7	2	17	162
50-74	107	47	12	7[3]	8[2]	23	204(3)
75-99	80	48	16	5[3]	6	20	175(1)
100-124	84	46	28	9	6	19[2]	192(2)
125-149	57	46	20	7	9	12[1]	151(1)
150-174	74	56	16	6	-[2,4]	11[1]	163(3)
175-199	48	30	12	7	4	10[2]	111(2)
200-224	43	29	8	3	2	5	90
225-249	38	25	7	2	2	4[2]	78(2)
250-274	25	18	5	2	-	2	52
275-299	28	13	1	-	-	-	42
300 & over	66	22	2	2	2	4	96
Totals	792	424	140	59	40	139	1584(14)

( ) Total Oregon airline routes.
1 Oregon airline has a route in this category in 1978.
2 Oregon airline has two routes in this category in 1978.
3 These Oregon airline routes give negative contribution in 1978.
4 One of these Oregon airline routes gives negative contribution in 1978.
NOTE--Based on 365 days regardless of number of days actually served. Data are not available on number of days served.

longer than average journey lengths, 155.7 sm versus 118.5 sm, and the markets are more dense, 48.25 passengers per day versus 8.12 passengers per day. It is not surprising that the airline is profitable; the data base airlines have journey statistics similar to Oregon.

5.4.6 Early and Late Flights Between Portland and Medford

The average percentage of total passenger traffic for each route segment for the four daily flights between Portland and Medford via the six western Oregon cities is shown in Table 5-27.

The first flight from Portland in the morning averages 3% of all passenger traffic on this route, and will also contain nearly all the inbound freight. The average air freight weight inbound is 494 pounds per station per day in 1978 (560 pounds per station per day in 1987). The revenue from air freight, assuming all inbound air freight arrives on this flight and an average mix of intra-Oregon and connecting traffic, raises the total revenue from 3% to 4.6% in 1978 compared to the average of 6.25%, based on 16 flights per day.

The fourth flight from Oregon cities, between Portland and Medford, to Portland averages 1.7% of all passenger traffic on this route. The average air freight weight outbound is 1153 pounds per station per day in 1978 (1307 pounds in 1987). The revenue from air freight, assuming all outbound air freight departs on this flight and an average mix of intra-Oregon and connecting traffic, raises the total revenue from 1.7% to 5.3% in 1978 compared to the average of 6.25%, based on 16 flights per day. Realistically, however, all air freight will not arrive and depart on these two flights.

Another method of increasing revenue on the first trip from Portland and the last trip to Portland is with diurnal differential fares. A cash savings on the morning flight of 30% is suggested (the same as a child's fare). On the evening flight the option of the 30% savings or a free, but modestly priced (≅$14) motel room near the airport (<3 sm) with free transportation to the city and the airport, could be provided. This last alternative is likely to be very popular with the Oregon businessman going to Portland for an early morning meeting because the morning flights are not scheduled to arrive before 10:10 A.M.

5.4.7 Connecting Traffic Summary

The connecting traffic southbound is the major inducement to a certificated carrier to cooperate in scheduling with the third-level airline. Certificated carriers, United Air Lines and Hughes Airwest, are currently scheduling 103-seat aircraft, B-737-200s and DC-9-30s, into Medford 2550 times per year and completing 2529 flights per year. They are boarding 102430 passengers which is equivalent to a 39.3% load factor. There is very little traffic carried through Medford because Eugene, Portland, and Seattle to the north have direct flights to San Francisco and Los Angeles, the main southern destinations. There is traffic from Salem through Medford to San Francisco, but this is assumed on the third-level airline's system (it has been removed from the Medford boardings given above).

TABLE 5-27

PERCENTAGE OF NORTH-SOUTH PASSENGERS BY FLIGHT IN 1978

Route	1st Flight	2nd Flight	3rd Flight	4th Flight	Route Total
Portland-*	3.0%[1]	5.9%	7.4%	7.7%	24.0%
* -Medford	6.0%	9.2%	6.8%	4.4%	26.4%
Medford-*	3.7%	7.2%	9.2%	5.9%	26.0%
* -Portland	7.9%	7.0%	7.0%	1.7%[2]	23.6%
	-----	-----	-----	-----	-----
% of Total	20.6%	29.3%	30.4%	19.7%	100.0%

* Weighted average of Corvallis-Albany, Klamath Falls, North Bend-Coos Bay, Redmond-Bend, Roseburg, and Salem.

1 Major inbound freight flight

2 Major outbound freight flight

It is proposed that the certificated carrier(s) schedule 2712 flights per year from Medford with two aircraft, the aircraft crossing at Medford; one coming from San Francisco and going to Eugene and Portland, and the other coming from Portland and Eugene and going to San Francisco, four times per day (Figure 5-1).

It is assumed that Hughes Airwest is the carrier and that United Airlines does not change its routes. It is also assumed that Hughes Airwest does not carry any Eugene-San Francisco traffic through Medford. This results in average load factors of 77.4% between San Francisco and Medford, 12.6% between Medford and Eugene, 43% between Eugene and Portland, and an average load factor for all segments of 52.6%; a figure above the systemwide average of Hughes Airwest.

If only one certificated aircraft is used flying between Medford and San Francisco it would have an average load factor of 77.4%, but it would not benefit the major Oregon markets of Medford-Portland, Medford-Eugene, and Eugene-Portland. A connecting traffic summary is given in Table 5-28.

An additional advantage to the certificated carrier is that its reservation system could be used, and much of the northbound connecting traffic from Oregon, through Portland, could be diverted to the its system. The diversion logic could be a negotiable item, i.e., how long a wait and how many stops would the connecting passenger be subjected to before the system looks for other airlines?

5.4.8 Newport

Newport was nearly included in the analysis. It was $15000 short of a positive contribution when served three times per day from Portland in 1978 (hub-and-spoke from Portland only). If the city and county governments were to contribute the $15000, service three times a day could be offered (twice on Saturday and Sunday). The contribution should be in the form of no landing fees, no building rental, and no utility costs to prevent the city from recovering the subsidy in user charges. The building, roads, and parking lot would have to meet the airline's specification. No other Oregon cities proved profitable without substantial cash subsidies in addition to cost relief.

5.4.9 Alternate Pricing Strategy

An alternate pricing strategy was tried which allowed prices for intra-Oregon travel (and air freight) to rise above the standard class fares (or fraction thereof). The only changes were price increases on the routes from Salem or Corvallis-Albany to Portland. These routes had negative contributions and price elasticities of -1.5% for intra-Oregon travel. The objective function was less negative if intra-Oregon traffic decreased, thereby decreasing costs, and if air freight revenue increased slightly. A 1% increase in fare resulted in a 0.65% increase in contribution. The pricing policy was rejected as unfair. Furthermore, past local traffic in these short-haul markets may have actually been connecting, but unaware of the availability of joint fares.

TABLE 5-28

CONNECTING TRAFFIC SUMMARY*

Station	Connecting Traffic Southbound	Mean Traffic Per Flight Southbound	Connecting Traffic Northbound
North Bend-Coos Bay	13869	5.115	5976
Roseburg	12765	4.708	5621
Corvallis-Albany	14573	5.375	5781
Salem	18101	6.676	6502
Klamath Falls	14370	5.300	5272
Redmond-Bend	12545	4.627	5079
Pendleton			21704
Baker-LaGrande			12899
TOTAL	86223	31.8	68834

*76.5% forecast to be boarded in the first year of flight operations.

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DEPARTMENT OF FLIGHT

Ph.D. THESIS

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J.D. GARNER

A methodology of investment appraisal for third-level airlines

Volume II

Supervisors: Prof. C.G.B. McClure
D.G. Yeomans

March, 1980

To Mom

"There are no hard decisions, just insufficient facts. When you have the facts, the decisions come easy."

George M. Humphrey
Former Secretary of the U.S. Treasury

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NOTATION

ADF	Automatic Direction Finder
AR	Affordable Risk
ARINC	Aeronautical Radio Incorporated
ATC	Air Traffic Control
BT	Block Time
C	Fixed Costs of Ownership
CAB	Civil Aeronautics Board
CAS	Calibrated Airspeed
CF_t	After-Tax Cashflow in Period "t", But Before Interest
Comm	Communications Radio
Con	Contribution
DME	Distance Measuring Equipment
DOC	Direct Operating Costs
DP	Dummy Variable for Portland
DPFI	Domestic Passenger Fare Investigation
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FBO	Fixed-Base Operator
FCC	Federal Communication Commission
FS	Fraction of Traffic Southbound
GS	Glideslope
GTOW	Gross Take-Off Weight (pounds)
hr	Hour(s)
HW	Headwind
i	Cost of Capital or Discount Rate
IFR	Instrument Flight Rules
IOC	Indirect Operating Costs
IRR	Internal-Rate-of-Return
IRS	Internal Revenue Service
ISA	International Standard Atmosphere
ITC	Investment Tax Credit
K( )	Coefficient or Calibration Constant of Regression
LOC	Localizer
MCTR	Mean-Cost-To-Repair
MKR	Marker Beacon Receiver
mph	Miles per Hour (statute)
MTBF	Mean-Time-Between-Failure
MTBMA	Mean-Time-Between-Maintenance-Action
MTBO	Mean-Time-Between-Overhaul
MTBR	Mean-Time-Between-Removal
MTBUR	Mean-Time-Between-Unscheduled-Removal
MTTR	Mean-Time-To-Repair
Nav	Navigation Radio (VOR)
NPV	Net-Present-Value
O&D	Origin & Destination Traffic
P( )	Probability of ( ) or Probability Density Function of ( )
PIM	Product of the Income-Weighted Taxable Income Distributions Multiplied by the Population Products
R	Revenue
RPHC	Rate Per Hour Contract
RPM	Revenue-Passenger-Miles
S	Opportunity Costs
SIC	Standard Industrial Classification
SPD	Subjective Probability Distribution
sm	Statute Mile(s)

NOTATION
(concl'd)

TBO	Time-Between-Overhaul
TSO	Technical Standard Order
U	Daily Utilization of Aircraft (hours)
U_1	Annual Utilization of Aircraft (hours)
V	Variable Costs
Vs	Short-term Variable (Escapable) Costs
VA	Volt-Amperes
VFR	Visual Flight Rules
VHF	Very High Frequency
VOR	Very High Frequency Omni-Range Navigation
WAT	Weight-Altitude-Temperature
WPIIC	Wholesale Price Index of Industrial Commodities
δ	Change Per Foot of Altitude
λ	Failure Rate
μ	Arithmetic Mean
σ	Standard Deviation
ΔT	Perceived Difference in Travel Time Between Travel Modes
^{o}C	Degrees Centigrade

6. RISK ANALYSIS

6.1 Introduction

This section develops the probability distributions around the regression lines and uses them in conjunction with the labor, nonlabor, material, and fuel cost-increase probability distributions to predict the probability distributions of operating cost. The operating cost distribution and the distributions of demand, developed from the regression statistics of the travel demand models, are fed into a modified route selection and pricing program which outputs the probable revenue-cost combinations. These combinations, along with start-up costs, ground equipment, traffic build-up rate, and inflation probabilities and aircraft financing possibilities are input to the PROSPER (PROfit Simulation Planning And Risk) risk analysis program, an ICL software package. PROSPER produces the probability distributions of cumulative cashflow and net-present-value (NPV) for the airline under different financing scenarios at selected discount rates. These are analyzed to determine the amount of cash required to begin operations and the proper financing decision.

6.1.1 Inputing Probability Distributions

The computer programs developed will not accept continuous probability density functions; therefore, an approximation of the function must be made. Specific values within the range of the probability density function are selected and given appropriate weightings (relative likelihoods). The process can be quite precise, but results in a frequency distribution which has discrete rather than continuous values of x and P(x) (Figure 6-1).

6.2 Distribution of Costs, Travel Demand, and Revenue

6.2.1 Distribution of Costs Found from Regression

Each observation in a regression analysis has an associated residual value. Residuals in the airline cost equations can result from differences in airline accounting practices or differences in airline structure. By forming a correlation matrix of the residuals we can determine how the airline parameters vary. For example, if there is positive correlation between the residuals of pilot and mechanic salaries then the airlines that paid pilots well also paid mechanics well and vice versa. If they had been negatively correlated, those airlines that paid pilots well would have paid mechanics poorly and vice versa. IOC labor may be negatively correlated with IOC nonlabor. This would be expected; presumably total costs are nearly the same though some airlines could do tasks manually and/or in-house (labor intensive) while others may be automated and/or send tasks out (nonlabor intensive). The simple correlation matrix of residuals is given in Table 6-1.

The only significant correlation at the 5% level is the negative correlation between mechanics salaries and IOC labor. As mentioned in Section 3.2.5, one airline had very high mechanic salaries. The operator said he could hire all the ticket agents, bookkeepers, and secretaries he needed for $500 per month. His airline provided four

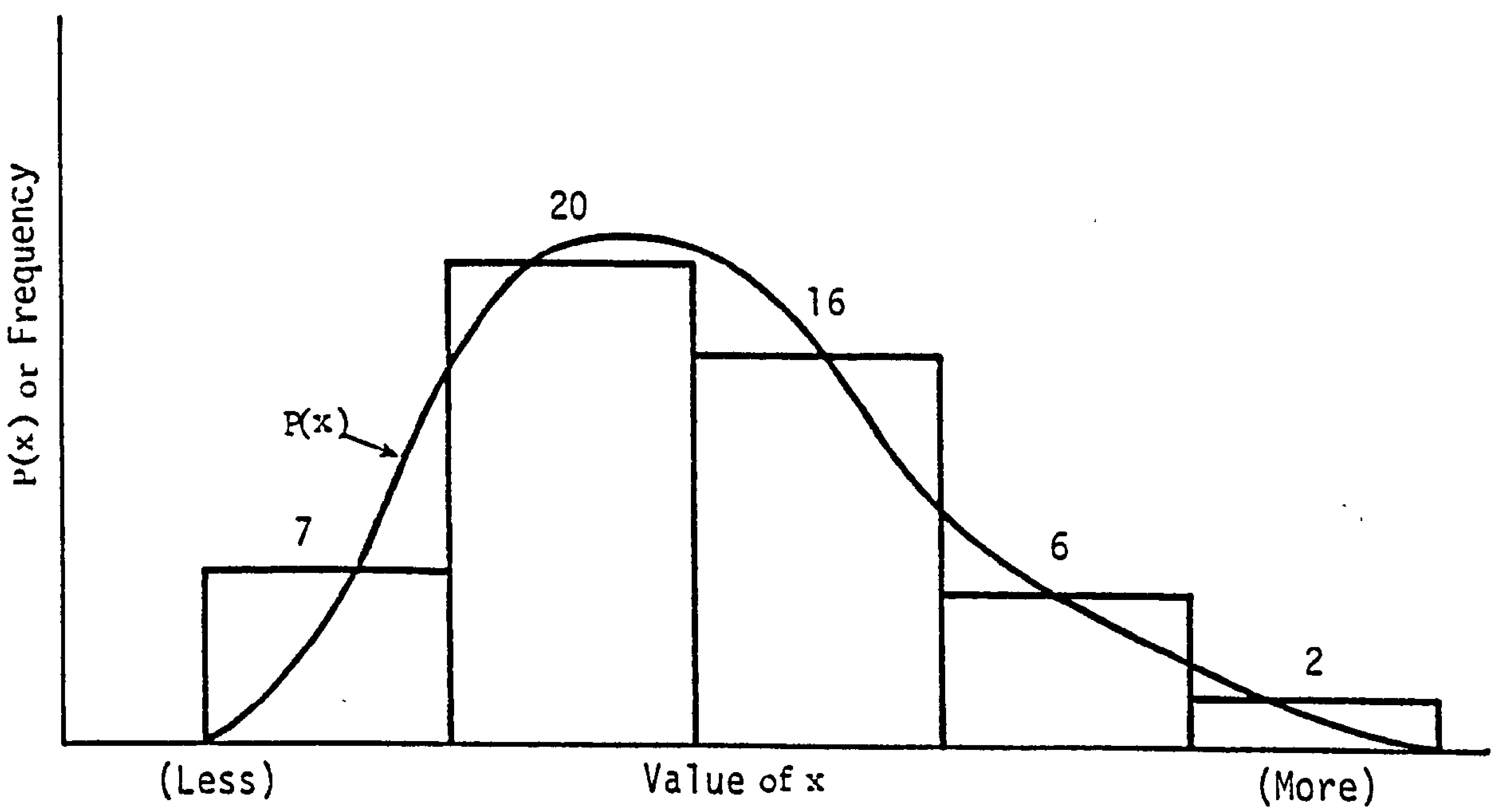


FIGURE 6-1
CONVERSION OF PROBABILITY DENSITY FUNCTION TO FREQUENCY DISTRIBUTION

TABLE 6-1

SIMPLE CORRELATION MATRIX OF RESIDUALS

	Number of Pilots	Number of IOC Employees	Mechanic Salaries	Pilot Salaries	IOC Labor Costs	IOC Nonlabor Costs
Number of Pilots	1.	0.035	0.277	0.146	-0.516	-0.273
Number of IOC Employees	0.035	1.	0.017	-0.286	0.429	-0.514
Mechanic Salaries	0.277	0.017	1.	0.072	-0.729	0.256
Pilot Salaries	0.146	-0.286	0.072	1.	-0.213	0.033
IOC Labor Costs	-0.516	0.429	-0.729	-0.213	1.	-0.478
IOC Nonlabor Costs	-0.273	-0.514	0.256	0.033	-0.478	1.

of the eleven observations. This, no doubt, influenced the matrix. However, it is doubtful that this is an industry-wide causal relationship. Some of the less significant correlations are interesting. Number-of-pilots is negatively correlated with both IOC labor and IOC nonlabor costs; this could mean that airlines with more pilots require them to perform more functions. Pilot salaries also correlate negatively with IOC labor costs enforcing the above and indicating that with more pilots performing more duties more money may be available to pay them.

The matrix in Table 6-1 was used with the forecast values and their estimated standard errors in conjuction with the equation below to determine the possible distribution of costs for the example airline.

$$\Delta C = \frac{\left(\sum_{m=1}^{6} \sum_{n=1}^{6} \rho_{mn} \Psi_m \Psi_n \tau^2 \sigma'_m \sigma'_n\right)^{0.5}}{RPM}$$

where

ΔC is the deviation from the mean variable cost per revenue-passenger-mile,

ρ_{mn} is the simple correlation of residuals m and n found in Table 6-1,

$\Psi_{m \text{ or } n}$ is the appropriate change in real terms for the period (1978 or 1987) and the variable (labor or nonlabor) in question,

τ is the number of standard deviations under consideration in each iteration (-1.53, -1.19, -0.85, -0.51, -0.17, 0.17, 0.51, 0.85, 1.19, 1.53),

$\sigma'_{m \text{ or } n}$ is expressed in dollars and found from

$$\sigma'_{m \text{ or } n} = \hat{\sigma}_{m \text{ or } n}(1 + \tilde{X}(X'X)^{-1}\tilde{X}')^{0.5}$$

where

$\sigma'_{m \text{ or } n}$ is the standard error of the regression equation at the forecast value,

$\hat{\sigma}_{m \text{ or } n}$ is the standard error as estimated (^) in the regression analysis,

X is an N x M matrix of independent variable observations (data) and X' is its transpose,

$\tilde{X}$ is an M-dimensional vector composed of the forecast values of the independent variable for which the variance is to be predicted (inputs) and $\tilde{X}'$ is the vector's transpose, and

RPM is the Revenue-Passenger-Miles in the year being computed (including air freight at 191 pound-miles per passenger-mile).

It was necessary to perform the calculation twice for each time period (1978 and 1987), once with all the elements at their proper values, and once with the nonlabor elements set to one ($\Psi = 1.0$) to allow the effects of nonlabor costs to be assessed. Nonlabor costs were negatively correlated with labor costs; hence, nonlabor costs actually decreased the spread of the distribution. The distribution of regression residuals is shown in Figure 6-2.

6.2.2 The Cost Simulation Program

Most-likely airline costs totaled $0.19633 per RPM in 1978. The breakdown of these costs is shown in Table 6-2. The costs were converted to probability distributions for 1978 and 1987 by a simulation program that picked randomly from the forecast labor growth rate frequency distribution (Figure 6-3), the forecast material growth rate frequency distribution (Figure 6-4), and the forecast crude oil growth rate distribution (Figure 6-5). (The 1978 values were obtained by running for a one year period then the mean increment was removed leaving a distribution about the original value.) After 10000 simulations, for both 1978 and 1987, the results were grouped into deciles. (See Appendix C for the decile grouping procedure.)

The 1978 and 1987 deciles were then converted to pentiles of similar shape by:

$$X_n = \frac{Y_{2n-1,1978} + Y_{2n,1978} + Y_{2n-1,1987} + Y_{2n,1987}}{4}$$

where

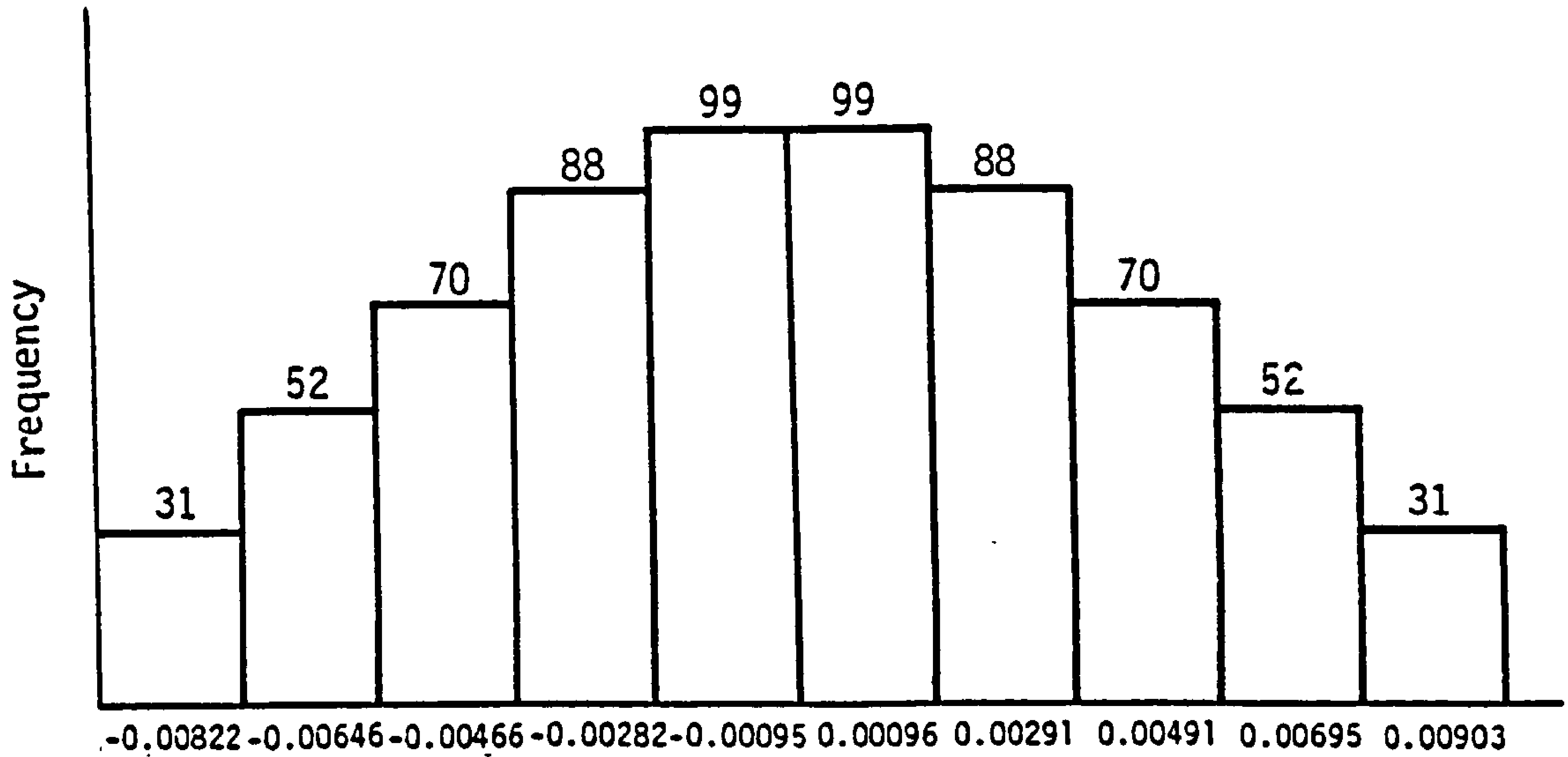
X_n is the number of values in the n^{th} pentile,

$n \in \{1,2,3,4,5\}$,

$Y_{2n-1,1978 \text{ or } 2n,1978}$ is the number of observations (out of 10000) in decile 2n-1 or 2n in 1978, and

$Y_{2n-1,1987 \text{ or } 2n,1987}$ is the number of observations (out of 10000) in decile 2n-1 or 2n in 1987.

The value of each pentile was then computed by taking the weighted average of the values in the pentile for both 1978 and 1987. This procedure was followed for both total cost and DOC cost (exclusive of the pilot and mechanic salaries RPM components). The total cost per RPM is shown in Figure 6-6. The marginal cost per RPM (indirect operating costs plus the pilot and mechanic RPM components) was obtained by subtracting the DOC cost from the total cost per RPM (Figure 6-7). The DOC cost was then converted to a ratio of the pentile values to the most-likely values in 1978 and 1987 (Figure 6-8). In the modified route selection and pricing program the marginal costs were entered directly and the DOC cost modifiers were entered to



Labor Cost Per Revenue-Passenger-Mile Distribution

0.00140 0.00102 0.00066 0.00035 0.00010 -0.00009 -0.00020 -0.00024 -0.00018 -0.00001

Nonlabor Cost Per Revenue-Passenger-Mile Distribution

1978 Distribution of Regression Residuals

-0.00811 -0.00638 -0.00460 -0.00279 -0.00094 0.00095 0.00289 0.00486 0.00689 0.00896

Labor Cost Per Revenue-Passenger-Mile Distribution

0.00129 0.00093 0.00060 0.00032 0.00009 -0.00008 -0.00018 -0.00020 -0.00014 0.00003

Nonlabor Cost Per Revenue-Passenger-Mile Distribution

1987 Distribution of Regression Residuals

FIGURE 6-2
DISTRIBUTION OF REGRESSION RESIDUALS

TABLE 6-2

COST BREAKDOWN FOR SIMULATION--1978

COST COMPONENT	COST
LABOR	
IOC Labor, Pilot (RPM Component)	$0.05065+X^{1}$
Pilots (nonRPM)	+ 0.01320
	$0.06385+X^{1}$
NONLABOR (Unchanging)	
IOC nonlabor	$0.02876+Y^{2}$
Aircraft Cost, Engines, Fuel & Oil (noncrude component), Mechanics, Burden, Insurance, Avionics	+ 0.07821
	$0.10697+Y^{2}$
FUEL AND OIL	
Crude Component	0.01421
MATERIAL	
Airframe & Systems Parts	+ 0.01130
TOTAL	$\$0.19633+X^{1}+Y^{2}$

1 A quantity randomly chosen from Labor Cost per Revenue-Passenger-Mile Distribution (Figure 6-2).

2 A quantity uniquely determined by the Labor Cost Per Revenue-Passenger-Mile (footnote 1 and Figure 6-2).

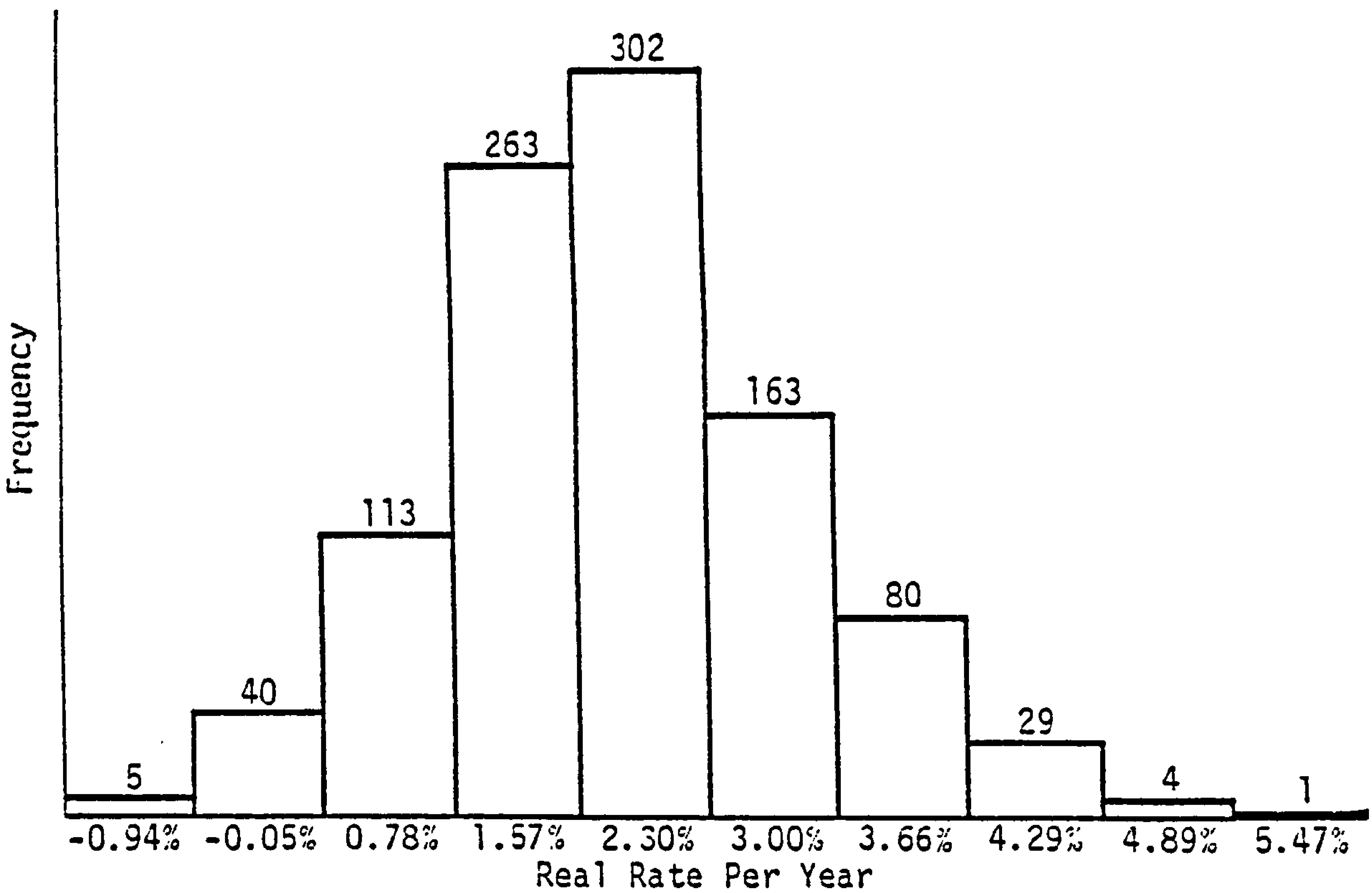


FIGURE 6-3
LABOR RATE FREQUENCY DISTRIBUTION

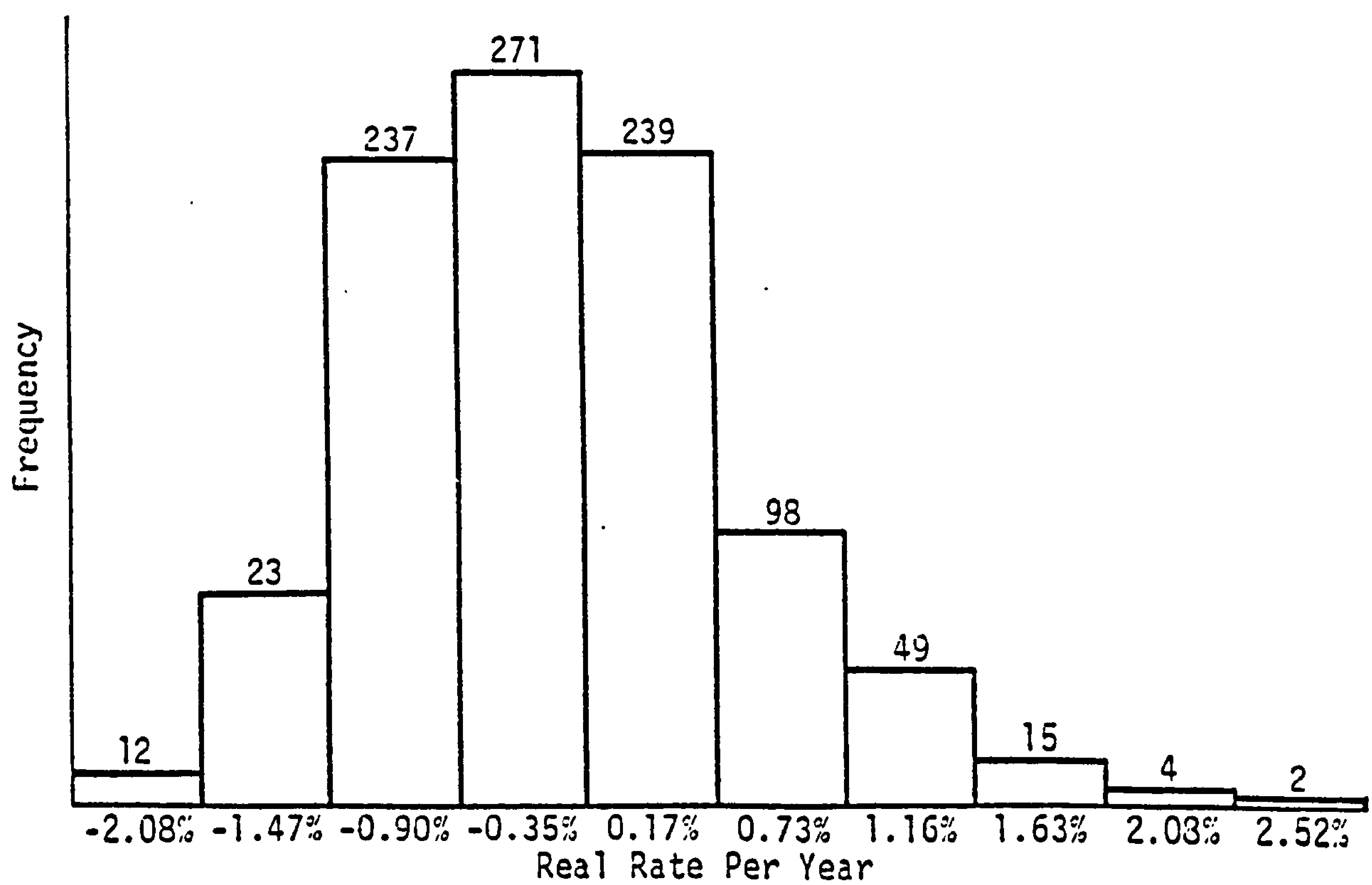


FIGURE 6-4
MATERIAL RATE FREQUENCY DISTRIBUTION

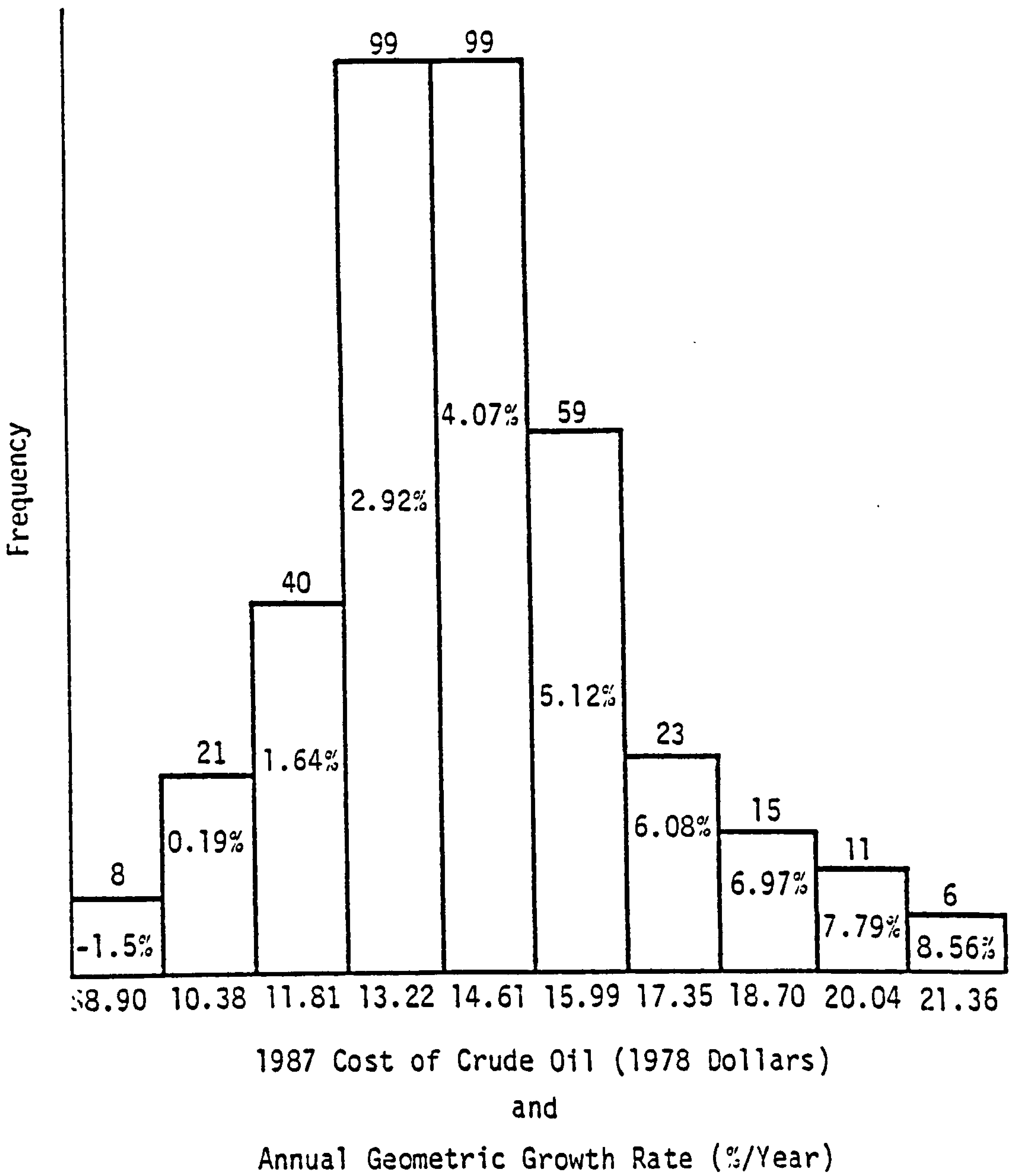


FIGURE 6-5
CRUDE OIL FREQUENCY DISTRIBUTION

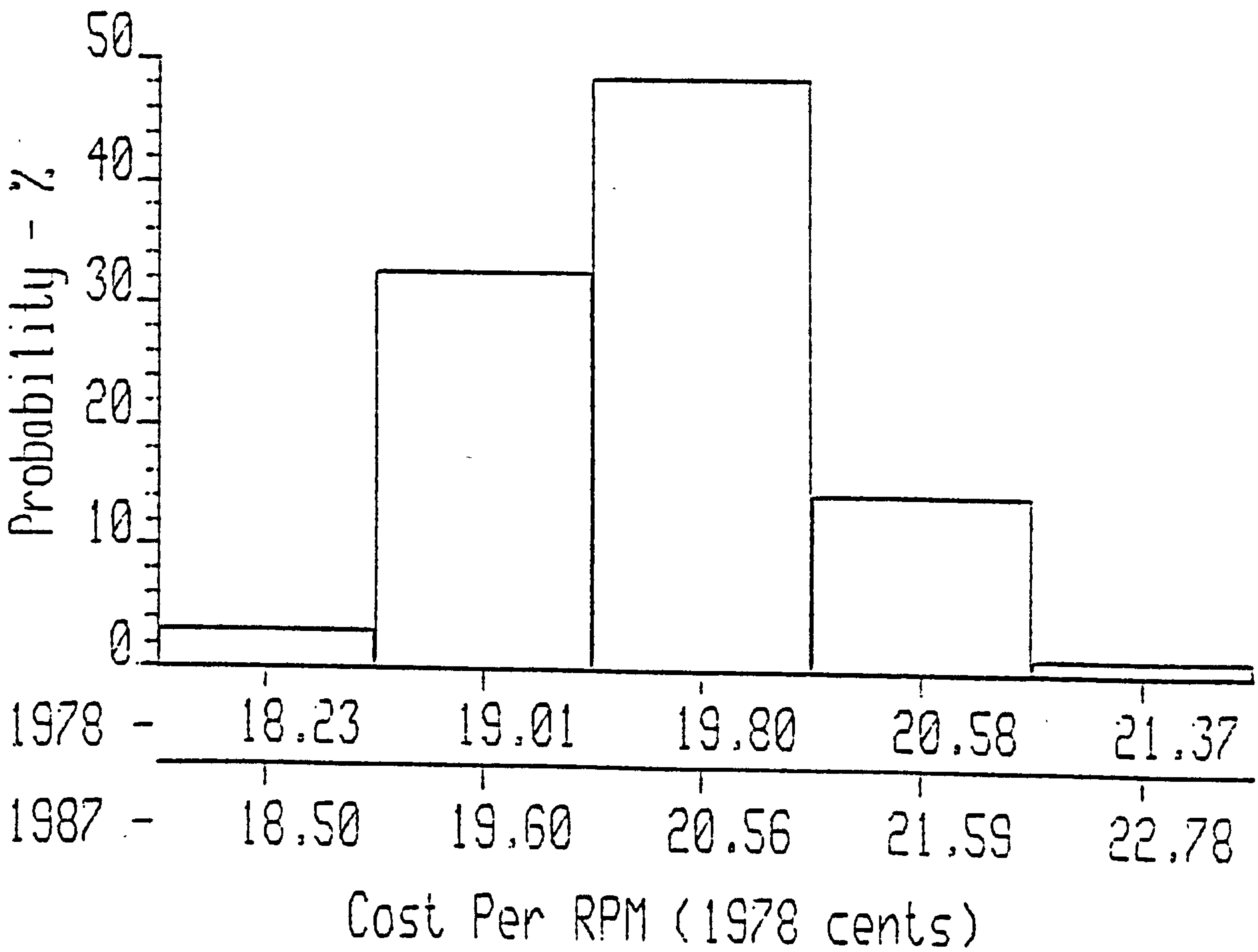


FIGURE 6-6
TOTAL COST PER RPM (1978 DOLLARS)

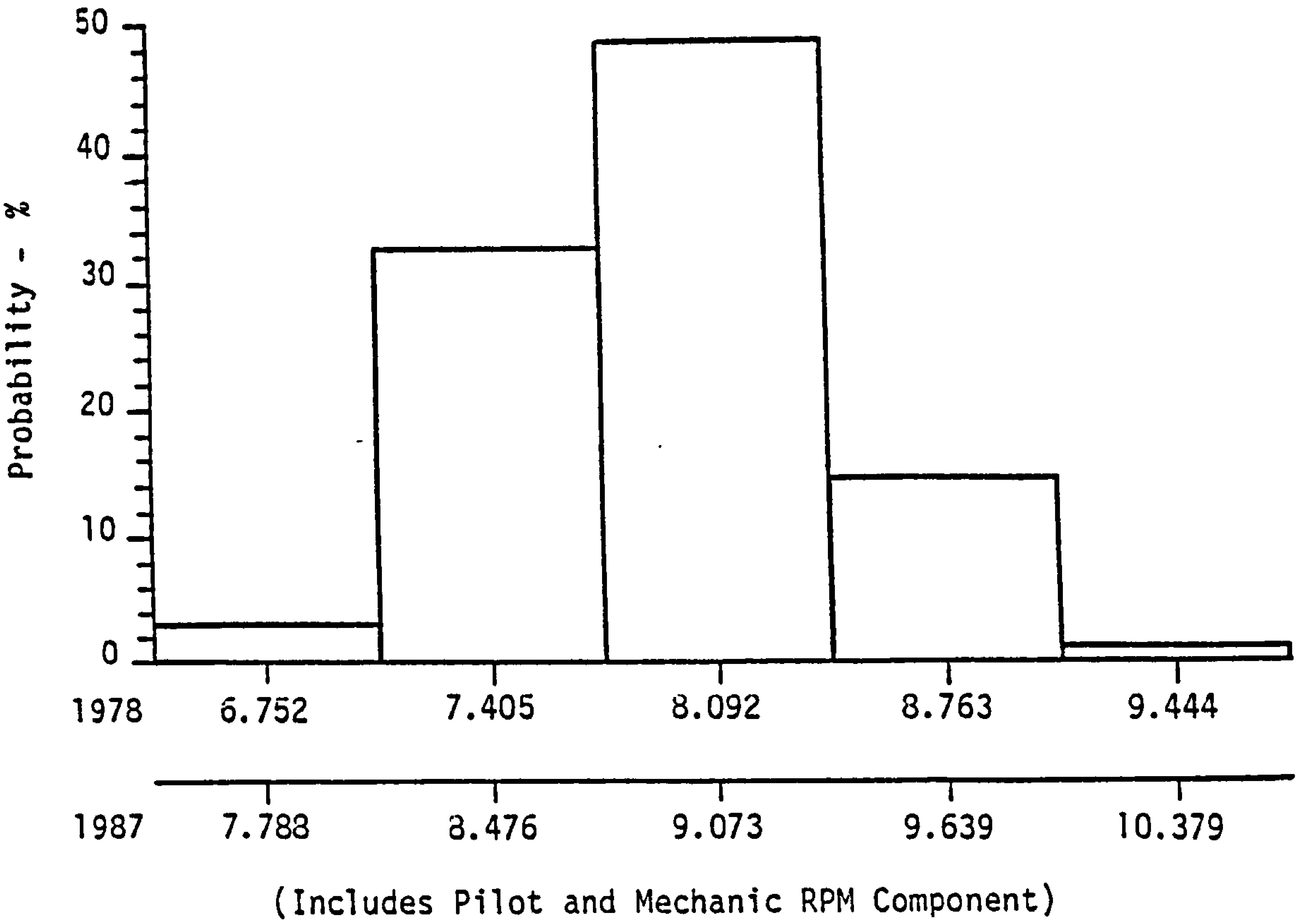


FIGURE 6-7
MARGINAL COST PER RPM (1978 DOLLARS)

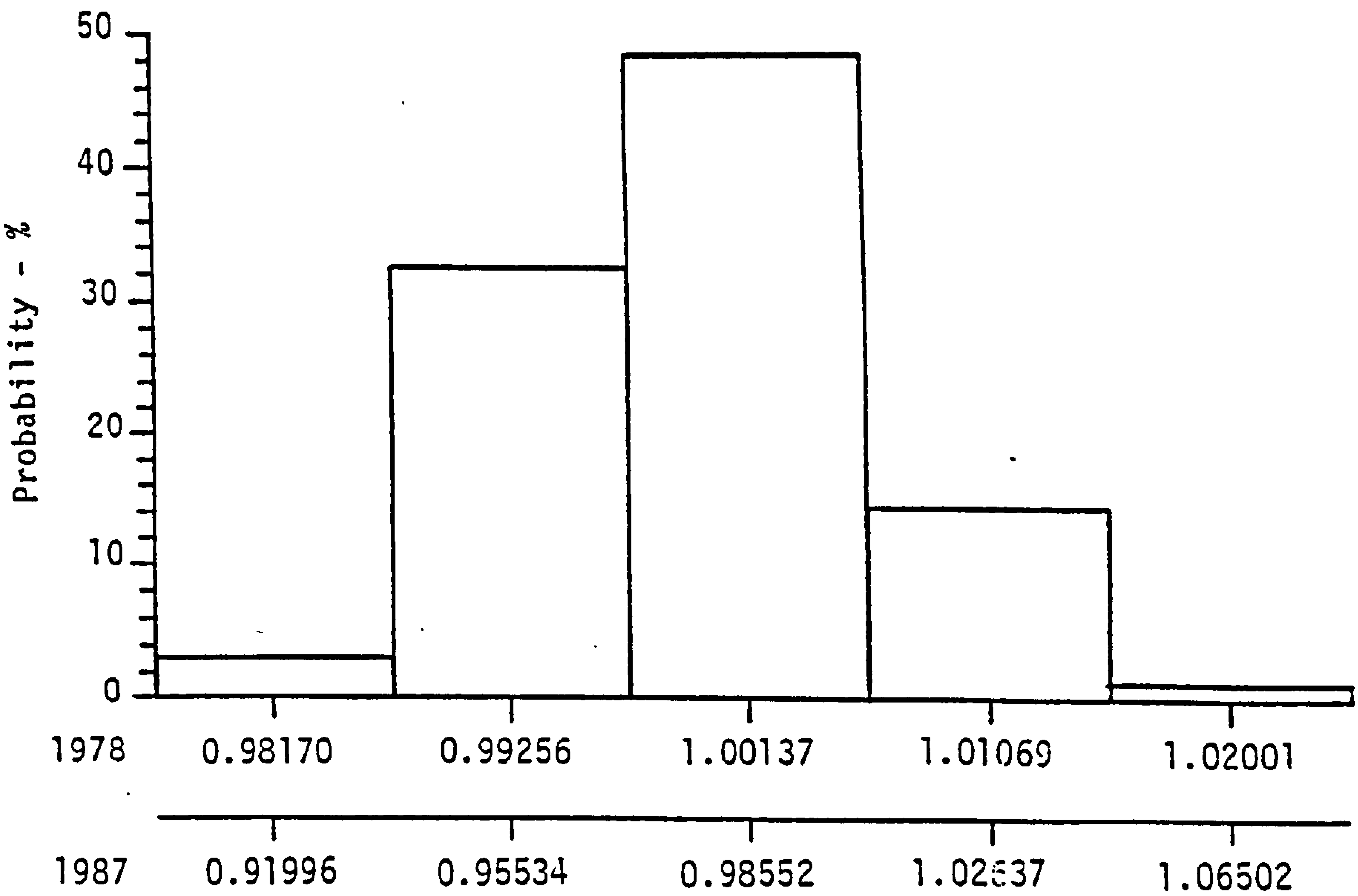


FIGURE 6-8
TRIP COST MODIFIERS

modify the trip costs that had already been input. Before this could be done, however, it was necessary to determine the probability distributions of the travel demand models.

6.2.3 Travel Demand Distributions

Each value forecast by the travel demand equations has a probability distribution associated with it corresponding to the following:

$$\sigma' = \hat{\sigma}(1 + \tilde{X}(X'X)^{-1}\tilde{X}')^{0.5}$$

where

σ' is the standard error of the regression equation at the forecast values,

$\hat{\sigma}$ is the standard error as estimated ($\hat{}$) by the regression,

X is an N x M matrix of independent variable observations (data) and X' is its transpose, and

$\tilde{X}$ is an M-dimensional vector composed of the forecast values (inputs) of the independent variable for which the variance is to be predicted and $\tilde{X}'$ is its transpose.

The resultant σ' for the three travel demand equations, for all routes or for all stations, were then multiplied by the factor:

$$N^{-0.5}$$

where

N is 14, representing the 14 routes of intra-Oregon travel demand, and

N is 8, representing the 8 stations of connecting travel demand and air freight demand.

It was then assumed that the relationship between intra-Oregon travel demand, connecting travel demand, and air freight demand was one of complete dependence. (It is reasonable to expect the travel demand models to be highly correlated.) This allowed the resultant deviations from the mean to be input with a one-to-one correspondence, with each value having a 20% probability (τ_1 = -1.28167, -0.84178, 0.0, 0.84178, 1.28167).

These two simplifying assumptions were made because a complete simulation, requiring 500 mill seconds per simulation on the ICL 1903T, was prohibitively expensive. The procedure was carried out for both time periods, 1978 and 1987.

6.2.4 Airline Cost and Revenue Distributions

The five equally probable values (20% probability) of travel demand were input into the route selection and price program along with five distinctly unequal values of possible costs (Figures 6-7 and 6-8).

The extreme annual statistics resulting from the simulation are shown in Table 6-3 for 1978 and Table 6-4 for 1987; τ_1 = -1.28167 and +1.28167 for both 1978 and 1987, and the extremes of total cost per RPM are 18.23¢ and 21.37¢ in 1978, and 18.50¢ and 22.78¢ in 1987.

There are points worth noting in Tables 6-3 and 6-4. Intra-Oregon travel is price-elastic, but connecting travel is not. Therefore, as costs go up intra-Oregon travel decreases because ticket prices rise. Connecting travel increases as the decrease in intra-Oregon demand makes more seats available and fewer connecting travelers are refused boarding. There is always enough air freight capacity under the assumptions of Section 5.3.3.2.4. Because of its greater standard error, air freight demand fluctuates the most. The costs per RPM given in Figure 6-6 are for the most-likely demand; they will vary with variations in demand, but this effect is not considered. Lastly, and most important, the airline always makes a positive contribution.

A final assumption was made. There was a one-to-one correspondence between travel pentiles and cost pentiles in 1978 and 1987. Thus, if τ_1 = -0.84178 and total cost per RPM equaled 20.58¢ in 1978, τ_1 = -0.84178 and total cost per RPM equaled 21.59¢ in 1987 (Figure 6-6).

Throughout the analysis, total annual aircraft ownership cost has been held constant, $1236367. This quantity was subtracted from each of the twenty-five variable cost values found in the simulation for both 1978 and 1987 to allow the actual financing decision to be made later in the PROSPER program.

On a one-to-one basis the rate of change in variable costs was found from:

$$GRC = \left[\frac{VC_{1987} - AC}{VC_{1978} - AC}\right]^{0.1} - 1$$

where

GRC is the annual growth rate of costs,

$VC_{1978,1987}$ is the variable cost in year 1978 or 1987, and

AC is the total annual cost of aircraft ownership, $1236367.

Similarly, for revenue:

$$GRR = \left[\frac{R_{1987}}{R_{1978}}\right]^{0.1} - 1$$

where

GRR is the annual growth rate of revenue, and

$R_{1978,1987}$ is the revenue in year 1978 or 1987.

TABLE 6-3

AIRLINE EXTREMES--1978

MINIMUM COST		MINIMUM DEMAND
ANNUAL DEMAND SERVED:		
LOCAL PASSENGERS PER YEAR		85794
TOTAL CONNECTING PASSENGERS PER YEAR		143811
TOTAL PASSENGERS SERVED PER YEAR		229605
PERCENTAGE OF PASSENGER DEMAND SERVED		97.60%
TOTAL FREIGHT PER YEAR - POUNDS		3191222.
PERCENTAGE OF FREIGHT DEMAND SERVED		100.00%
REVENUE (AFTER TICKET TAX):		
ANNUAL REVENUE FROM LOCAL TRAFFIC	$	3336130.
ANNUAL REVENUE FROM CONNECTING TRAFFIC	$	5471980.
ANNUAL REVENUE FROM MAIL AND FREIGHT	$	291782.
TOTAL ANNUAL REVENUE	$	9099892.
TOTAL ANNUAL VARIABLE COSTS	$	7473859.
ANNUAL AIRLINE CONTRIBUTION	$	1626033.
AIRLINE AVERAGE LOAD FACTOR		34.49%
TOTAL REVENUE PASSENGER MILES PER YEAR		37863511.
% OF REVENUE PASSENGER MILES IN FREIGHT		5.44%
VARIABLE COST PER REVENUE PASSENGER MILE	$	0.197389

MAXIMUM COST		MINIMUM DEMAND
ANNUAL DEMAND SERVED:		
LOCAL PASSENGERS PER YEAR		80342
TOTAL CONNECTING PASSENGERS PER YEAR		143848
TOTAL PASSENGERS SERVED PER YEAR		224190
PERCENTAGE OF PASSENGER DEMAND SERVED		97.66%
TOTAL FREIGHT PER YEAR - POUNDS		3191222.
PERCENTAGE OF FREIGHT DEMAND SERVED		100.00%
REVENUE (AFTER TICKET TAX):		
ANNUAL REVENUE FROM LOCAL TRAFFIC	$	3226864.
ANNUAL REVENUE FROM CONNECTING TRAFFIC	$	5487185.
ANNUAL REVENUE FROM MAIL AND FREIGHT	$	297246.
TOTAL ANNUAL REVENUE	$	9011295.
TOTAL ANNUAL VARIABLE COSTS	$	8184941.
ANNUAL AIRLINE CONTRIBUTION	$	826354.
AIRLINE AVERAGE LOAD FACTOR		33.68%
TOTAL REVENUE PASSENGER MILES PER YEAR		36774444.
% OF REVENUE PASSENGER MILES IN FREIGHT		5.60%

TABLE 6-3
(Concl'd)

AIRLINE EXTREMES--1978

MINIMUM COST MAXIMUM DEMAND

ANNUAL DEMAND SERVED:		
LOCAL PASSENGERS PER YEAR		101356
TOTAL CONNECTING PASSENGERS PER YEAR		167021
TOTAL PASSENGERS SERVED PER YEAR		268377
PERCENTAGE OF PASSENGER DEMAND SERVED		97.24%
TOTAL FREIGHT PER YEAR - POUNDS		5461710.
PERCENTAGE OF FREIGHT DEMAND SERVED		100.00%
REVENUE (AFTER TICKET TAX):		
ANNUAL REVENUE FROM LOCAL TRAFFIC	$	4047920.
ANNUAL REVENUE FROM CONNECTING TRAFFIC	$	6363476.
ANNUAL REVENUE FROM MAIL AND FREIGHT	$	508798.
TOTAL ANNUAL REVENUE	$	10920194.
TOTAL ANNUAL VARIABLE COSTS	$	8029868.
ANNUAL AIRLINE CONTRIBUTION	$	2890325.
AIRLINE AVERAGE LOAD FACTOR		40.39%
TOTAL REVENUE PASSENGER MILES PER YEAR		45510455.
% OF REVENUE PASSENGER MILES IN FREIGHT		7.88%
VARIABLE COST PER REVENUE PASSENGER MILE	$	0.176440

MAXIMUM COST MAXIMUM DEMAND

ANNUAL DEMAND SERVED:		
LOCAL PASSENGERS PER YEAR		97849
TOTAL CONNECTING PASSENGERS PER YEAR		167089
TOTAL PASSENGERS SERVED PER YEAR		264938
PERCENTAGE OF PASSENGER DEMAND SERVED		97.32%
TOTAL FREIGHT PER YEAR - POUNDS		5461710.
PERCENTAGE OF FREIGHT DEMAND SERVED		100.00%
REVENUE (AFTER TICKET TAX):		
ANNUAL REVENUE FROM LOCAL TRAFFIC	$	3961461.
ANNUAL REVENUE FROM CONNECTING TRAFFIC	$	6376623.
ANNUAL REVENUE FROM MAIL AND FREIGHT	$	514539.
TOTAL ANNUAL REVENUE	$	10852623.
TOTAL ANNUAL VARIABLE COSTS	$	8890177.
ANNUAL AIRLINE CONTRIBUTION	$	1962446.
AIRLINE AVERAGE LOAD FACTOR		39.80%
TOTAL REVENUE PASSENGER MILES PER YEAR		44681563.
% OF REVENUE PASSENGER MILES IN FREIGHT		8.03%

TABLE 6-4

AIRLINE EXTREMES--1987

MINIMUM COST		MINIMUM DEMAND
ANNUAL DEMAND SERVED:		
LOCAL PASSENGERS PER YEAR		91089
TOTAL CONNECTING PASSENGERS PER YEAR		163654
TOTAL PASSENGERS SERVED PER YEAR		254743
PERCENTAGE OF PASSENGER DEMAND SERVED		97.21%
TOTAL FREIGHT PER YEAR - POUNDS		3683235.
PERCENTAGE OF FREIGHT DEMAND SERVED		100.00%
REVENUE (AFTER TICKET TAX):		
ANNUAL REVENUE FROM LOCAL TRAFFIC	$	3626101.
ANNUAL REVENUE FROM CONNECTING TRAFFIC	$	6227889.
ANNUAL REVENUE FROM MAIL AND FREIGHT	$	341244.
TOTAL ANNUAL REVENUE	$	10195234.
TOTAL ANNUAL VARIABLE COSTS	$	8065680.
ANNUAL AIRLINE CONTRIBUTION	$	2129554.
AIRLINE AVERAGE LOAD FACTOR		40.16%
TOTAL REVENUE PASSENGER MILES PER YEAR		41636573.
% OF REVENUE PASSENGER MILES IN FREIGHT		5.70%
VARIABLE COST PER REVENUE PASSENGER MILE	$	0.193716

MAXIMUM COST		MINIMUM DEMAND
ANNUAL DEMAND SERVED:		
LOCAL PASSENGERS PER YEAR		86384
TOTAL CONNECTING PASSENGERS PER YEAR		163716
TOTAL PASSENGERS SERVED PER YEAR		250100
PERCENTAGE OF PASSENGER DEMAND SERVED		97.27%
TOTAL FREIGHT PER YEAR - POUNDS		3683235.
PERCENTAGE OF FREIGHT DEMAND SERVED		100.00%
REVENUE (AFTER TICKET TAX):		
ANNUAL REVENUE FROM LOCAL TRAFFIC	$	3519980.
ANNUAL REVENUE FROM CONNECTING TRAFFIC	$	6244816.
ANNUAL REVENUE FROM MAIL AND FREIGHT	$	347089.
TOTAL ANNUAL REVENUE	$	10111885.
TOTAL ANNUAL VARIABLE COSTS	$	9807083.
ANNUAL AIRLINE CONTRIBUTION	$	304803.
AIRLINE AVERAGE LOAD FACTOR		39.43%
TOTAL REVENUE PASSENGER MILES PER YEAR		40675387.
% OF REVENUE PASSENGER MILES IN FREIGHT		5.84%

TABLE 6-4
(Concl'd)

AIRLINE EXTREMES--1987

MINIMUM COST — MAXIMUM DEMAND

ANNUAL DEMAND SERVED:		
LOCAL PASSENGERS PER YEAR		109115
TOTAL CONNECTING PASSENGERS PER YEAR		189081
TOTAL PASSENGERS SERVED PER YEAR		298196
PERCENTAGE OF PASSENGER DEMAND SERVED		96.28%
TOTAL FREIGHT PER YEAR - POUNDS		6288787.
PERCENTAGE OF FREIGHT DEMAND SERVED		100.00%
REVENUE (AFTER TICKET TAX):		
ANNUAL REVENUE FROM LOCAL TRAFFIC	$	4408657.
ANNUAL REVENUE FROM CONNECTING TRAFFIC	$	7200302.
ANNUAL REVENUE FROM MAIL AND FREIGHT	$	590181.
TOTAL ANNUAL REVENUE	$	12199140.
TOTAL ANNUAL VARIABLE COSTS	$	8717424.
ANNUAL AIRLINE CONTRIBUTION	$	3481716.
AIRLINE AVERAGE LOAD FACTOR		47.01%
TOTAL REVENUE PASSENGER MILES PER YEAR		50008367.
% OF REVENUE PASSENGER MILES IN FREIGHT		8.18%
VARIABLE COST PER REVENUE PASSENGER MILE	$	0.174319

MAXIMUM COST — MAXIMUM DEMAND

ANNUAL DEMAND SERVED:		
LOCAL PASSENGERS PER YEAR		106871
TOTAL CONNECTING PASSENGERS PER YEAR		189153
TOTAL PASSENGERS SERVED PER YEAR		296024
PERCENTAGE OF PASSENGER DEMAND SERVED		96.35%
TOTAL FREIGHT PER YEAR - POUNDS		6288787.
PERCENTAGE OF FREIGHT DEMAND SERVED		100.00%
REVENUE (AFTER TICKET TAX):		
ANNUAL REVENUE FROM LOCAL TRAFFIC	$	4356339.
ANNUAL REVENUE FROM CONNECTING TRAFFIC	$	7210519.
ANNUAL REVENUE FROM MAIL AND FREIGHT	$	594891.
TOTAL ANNUAL REVENUE	$	12161748.
TOTAL ANNUAL VARIABLE COSTS	$	10727532.
ANNUAL AIRLINE CONTRIBUTION	$	1434215.
AIRLINE AVERAGE LOAD FACTOR		46.67%
TOTAL REVENUE PASSENGER MILES PER YEAR		49543416.
% OF REVENUE PASSENGER MILES IN FREIGHT		8.26%

The five different values of cost and the five different values of travel demand yielded twenty-five sets of four values (VC_{1978}, GRC, R_{1978}, GRR) to be entered in the final simulation program with an appropriate weighting of cost (2.93%, 32.68%, 48.3%, 14.63%, 1.46%) versus travel (20%, 20%, 20%, 20%, 20%); see Table 6-5.

6.3 PROSPER Simulation

The PROSPER simulation evaluates methods of aircraft finance, timing of payments and revenue, start-up costs in 1978 and wind-up effects in 1987. Its outputs are the completed airline simulation.

6.3.1 Aircraft Financing Options

By far the most important decision remaining, after the routes and equipment are selected, is how the aircraft will be financed. Four options were considered. First, the aircraft could be purchased outright in the traditional concept of a self-contained business owning its own capital equipment. Second, the airline could be operated as a tax shelter where the airline purchases the equipment, but is a subsidiary of another firm which uses the tax benefits the airline generates, but cannot use in its early years. Third, the airline could lease its aircraft from a firm that retains the aircraft depreciation benefits. Fourth, the airline could lease the aircraft from a firm that retains both the aircraft depreciation and investment tax credit benefits.

6.3.1.1 Debt Financing

Purchasing an aircraft where financing is done in the usual sense (down payment, installment payments, balance sheet ownership) is termed debt financing.

The advantages of debt financing are given below:

1. The utilization of depreciation and investment tax credit benefits result in lower taxable corporate profits.

2. The dilution of stockholder investment is minimized.

3. The return on common stock is greater when earnings exceed the cost of debt.

4. It provides the pride and security of ownership, the use throughout the life, and the salvage value, of the aircraft.

The disadvantages of debt financing are given below:

1. No profit means no benefit from depreciation and investment tax credit (and there is a limit on the carrying forward/back of a tax loss).

2. Debt capital will be expensive if earnings are low.

3. Debt-financed firms used to appear more highly leveraged than lease-financed firms (IRS now requires leases be capitalized).

TABLE 6-5

COST, COST GROWTH, REVENUE, AND REVENUE GROWTH
FROM THE MODIFIED ROUTE SELECTION AND PRICING PROGRAM
(1978 DOLLARS)

Probability (%)	Cost ($/Period)	Cost Growth (%/Year)	Revenue ($/Period)	Revenue Growth (%/Year)
0.585	1039582	1.01	1516640	1.27
6.537	1067724	1.43	1514455	1.26
9.658	1097979	1.68	1509895	1.25
2.927	1132017	1.93	1505908	1.26
0.293	1158096	2.36	1501883	1.29
0.585	1067373	1.03	1602710	1.26
6.537	1094290	1.45	1598078	1.26
9.658	1126625	1.71	1593991	1.26
2.927	1164112	1.92	1591673	1.25
0.293	1191345	2.37	1587490	1.28
0.585	1093690	1.04	1661264	1.26
6.537	1115430	1.44	1660594	1.24
9.658	1148864	1.68	1656458	1.23
2.927	1183319	1.83	1649826	1.27
0.293	1213305	2.39	1647424	1.29
0.585	1104154	1.06	1725635	1.25
6.537	1135181	1.46	1723303	1.23
9.658	1166722	1.71	1719090	1.23
2.927	1207809	1.98	1714758	1.26
0.293	1236787	2.42	1710342	1.29
0.585	1132250	1.08	1820032	1.24
6.537	1166971	1.47	1820032	1.22
9.658	1203258	1.74	1815733	1.23
2.927	1243273	2.01	1811284	1.26
0.293	1275635	2.42	1808770	1.27

100%				

6.3.1.2 Tax Sheltering

A tax shelter exists when the tax benefits generated by the airline are used by another firm or individual. A lease is a tax shelter to the lessor because the lessor can use the tax benefits of the aircraft, but here tax shelter refers to the whole airline (the majority (≅90%) of the tax benefits are still provided by the aircraft).

The tax shelter in this analysis is structured so that the airline has first call on its tax benefits. If the airline can not use the tax benefits in the year they occur, they are transferred to the parent firm where they are assumed to be used immediately.

The advantages of a tax shelter are given below:

1. The advantages of debt financing.

2. The maximum net-present-value is received for depreciation and investment tax credit, if these benefits can be used immediately.

3. The airline has the support of a larger, presumably more secure, firm.

The disadvantages of a tax shelter are given below:

1. The airline will appear in the worst light if it is profitable, yet can't utilize its own depreciation or investment tax credit.

2. The parent firm may be unfamiliar with the industry, and may not understand the peculiarities of airlines. (This could be particularly true if the parent firm is a product industry, as opposed to a service industry.)

6.3.1.3 Leasing

A lease is an arrangement where a firm with capital purchases aircraft in order to receive the tax benefits and make a return-on-investment. It leases the aircraft to an airline which cannot or does not wish to purchase them.

There are two main types of leases:

An operating lease is a short-term lease. Short-term being defined as less than a major portion of the serviceable life of the aircraft. The prime requirement for equipment to be short-term leased is that it be easy to move, e.g., B727-200 (easily leasable within 30 days after servicing and painting). This lease is not available to third-level airlines because their equipment is not in sufficiently high demand.

A financial lease is a long-term lease. Long-term being defined as a major portion of the serviceable life of the aircraft. To qualify as a lease the Internal Revenue Service (IRS) requires a 15% residual value, based on the original purchase price, be remaining two years after the expiration of the lease. This is the only type of lease available to third-level airlines. There are usually provisions (besides financial) regarding maintenance, spare parts, insurance, engine reserves, default, and cancellation.

There are three common options with a financial lease: the lessor retains the depreciation and the investment tax credit, the lessor gets the depreciation and the lessee (airline) gets the investment tax credit, and the lease is really a conditional sale so the lessee retains part of the depreciation and all the investment tax credit. In the conditional sale, the lessee has the right to purchase the aircraft at much less than the fair-market value. In this case, the IRS says the airline has gained an equity position; hence, it can retain depreciation.

The first option minimizes the monthly cash outflow of the airline. The conditional sale requires the greatest monthly cash outflow. The conditional sale is not investigated further because the terms are usually similar to debt financing.

The advantages of leasing to the lessee (airline) are given below:[74]

1. It leaves working capital available and part of the benefits of the early use of depreciation (and investment tax credit) are passed on to the lessee.

2. It facilitates budgeting and planning, and offers a hedge against inflation if fixed-rate financing can be arranged. (The unstable financial market has caused recent leases to be linked to the prime rate eliminating this advantage.)

3. Reduces the funding required to start up.

4. Leasing used to keep an obligation off the balance sheet that was as binding as debt; the lease must now be capitalized, a requirement of the Internal Revenue Service. (In 1974 the certificated carriers debt as a percentage of capitalization was 57%. With leases included as debt, the percentage would have been 70%.[76])

5. Avoids progress payments to the manufacturer.

6. Simplifies bookkeeping for tax purposes.

7. Reduces the risk of technical obsolescence.[75]

The disadvantages of leasing to the lessee (airline) are given below:[74]

1. No pride or security of ownership, salvage value, or use past the end of the contract.

2. If the airline is profitable, it loses part of its tax benefits.

3. Some argue that leasing makes aircraft too easy to obtain thereby adding to industry overcapacity problems.[76]

The advantages of leasing to lessor (vendor) are given below:

1. Individuals in high tax brackets form investment partnerships (subchapter S Corporations) to purchase aircraft, and, using the aircraft as security, borrow a high proportion of its purchase price ultimately leasing the aircraft to an airline. The high marginal tax rates of the partners make the tax shelter provided by the interest on their borrowed funds and the accelerated depreciation of the aircraft more valuable to them than to the airline. (By passing along part of the savings to the airline, they try to make leasing more attractive than owning.)

2. Investment Tax Credit (ITC) provides an immediate tax shelter equal to 10% (11% for a subchapter S corporation) of the capital invested, as long as the equipment is retained for at least 7 years.

The disadvantages to the lessor (vendor) are given below:

1. He may be left with capital equipment he cannot operate if the airline goes bankrupt (receivership).

2. He may have trouble re-leasing the equipment.

3. He may have over-estimated the residual value.

6.3.1.4 Outright Purchase Versus Lease

The outright purchase is superior to leasing if:[77]

1. The net salvage value of the assets exceeds the extra costs of owning.

2. The purchase price minus useable tax benefits (depreciation and investment tax credit) is less than the burden of the lease payments.

The whole problem, and the reason for the analysis, is that the investment required must be discounted (or inflated) to some common time, usually project initiation, at an appropriate average-weighted cost of captial.

6.3.2 The Inputs to PROSPER

6.3.2.1 Start-Up Timings

Third-level operators were queried as to the timings of various events during start up. Six months was given as the expected time between the incorporation and the earliest scheduled flight. This corresponded to the airframe manufacturers' estimates of the time from order to delivery of line-ready aircraft with factory trained flight crews and mechanics (airline hired).

The key personnel are the general manager, chief pilot, chief of maintenance, financial officer, and marketing manager. They will be needed from the time of incorporation.

Pilots and mechanics must be hired one to one and a half months before they can be used in scheduled service. Reservation and sales staff require much less training, and can be hired and trained two weeks before they are needed.

During the first six months the airline must organize temporary (transitioning to permanent) office, shop, and hangar space. Regulatory hearings may be required on the local, state, and national level. The cost of these hearings has been estimated at $9000 per community.[11]

The organizational expense, and key personnel salaries are shown in Figure 6-9. The regulatory hearing expenses, training expenses, and salaries for other than key personnel were handled by advancing expenses by one time period (six time periods per year). These expenses are the variable costs in Table 6-5. They average $1139746 for training and hiring in the start-up periods.

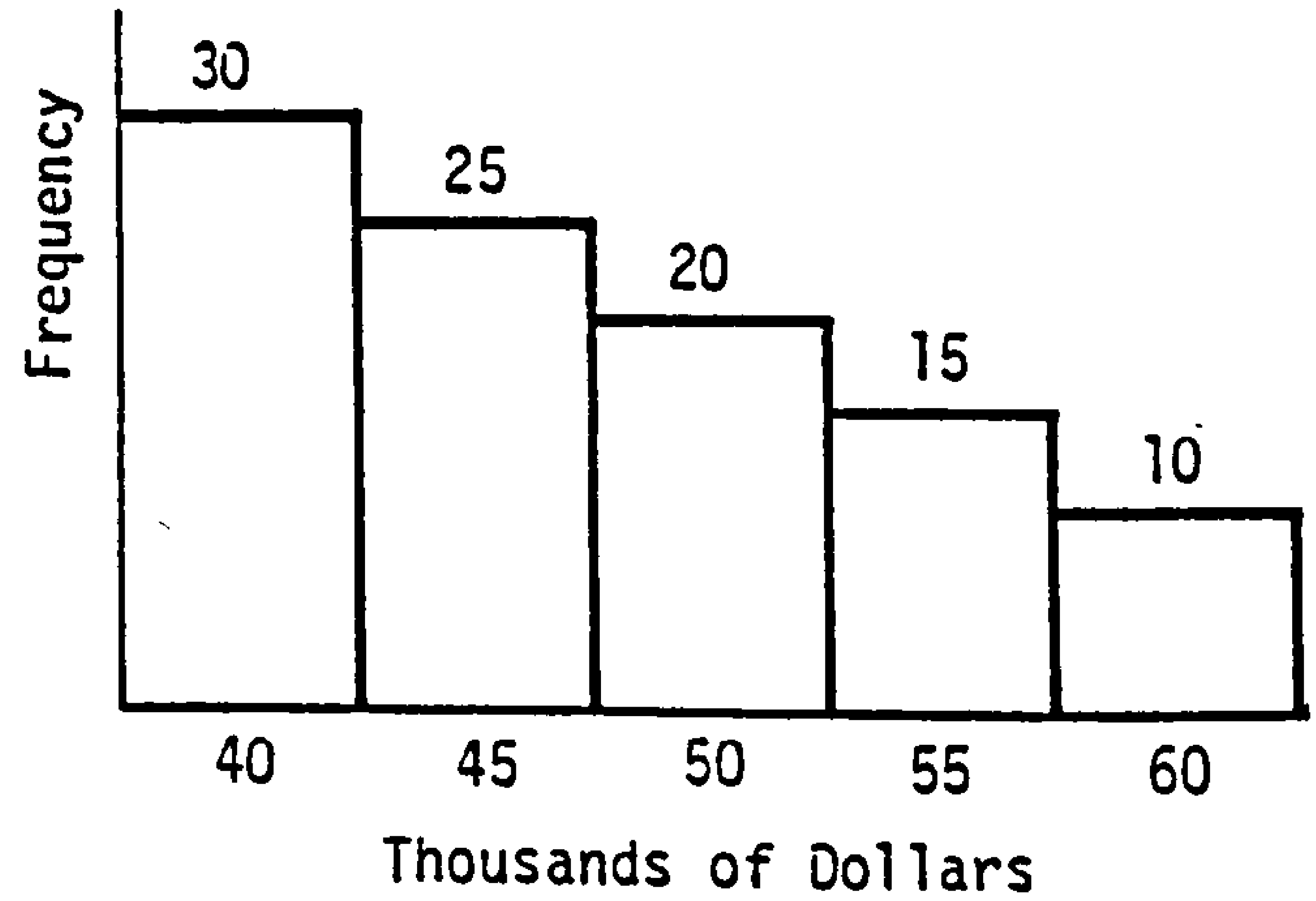


FIGURE 6-9
ORGANIZATIONAL EXPENSE AND INITIAL SALARIES

Total variable costs (Table 6-5) are factored by 0.375 in the second period, 0.75 in the third period and 1.0 from the fourth period onwards. These fractions correspond to the number of aircraft available (3,6,8) in each period divided by the number of aircraft routes (8). Normally, the airline would try to start the most profitable routes first. In this instance the most profitable routes are still served by certificated carriers. The exact timing of the departure of the certificated carrier is unknown, so only average route values were assumed.

6.3.2.2 Inflation and the Prime Rate

The frequency distribution of the inflation rate is determined in Appendix C and shown in Figure 6-10A. The prime rate was found to be a function of the inflation rate as represented in the equation:

$$\Delta P = K1 + K2\ I$$

where

ΔP is the difference between the prime rate and the inflation rate in percent per year,

K1 (3.93820) is the intercept,

K2 (-0.43998) is the decrease of ΔP with the increase in the inflation rate, and

I is the inflation rate in percent per year.

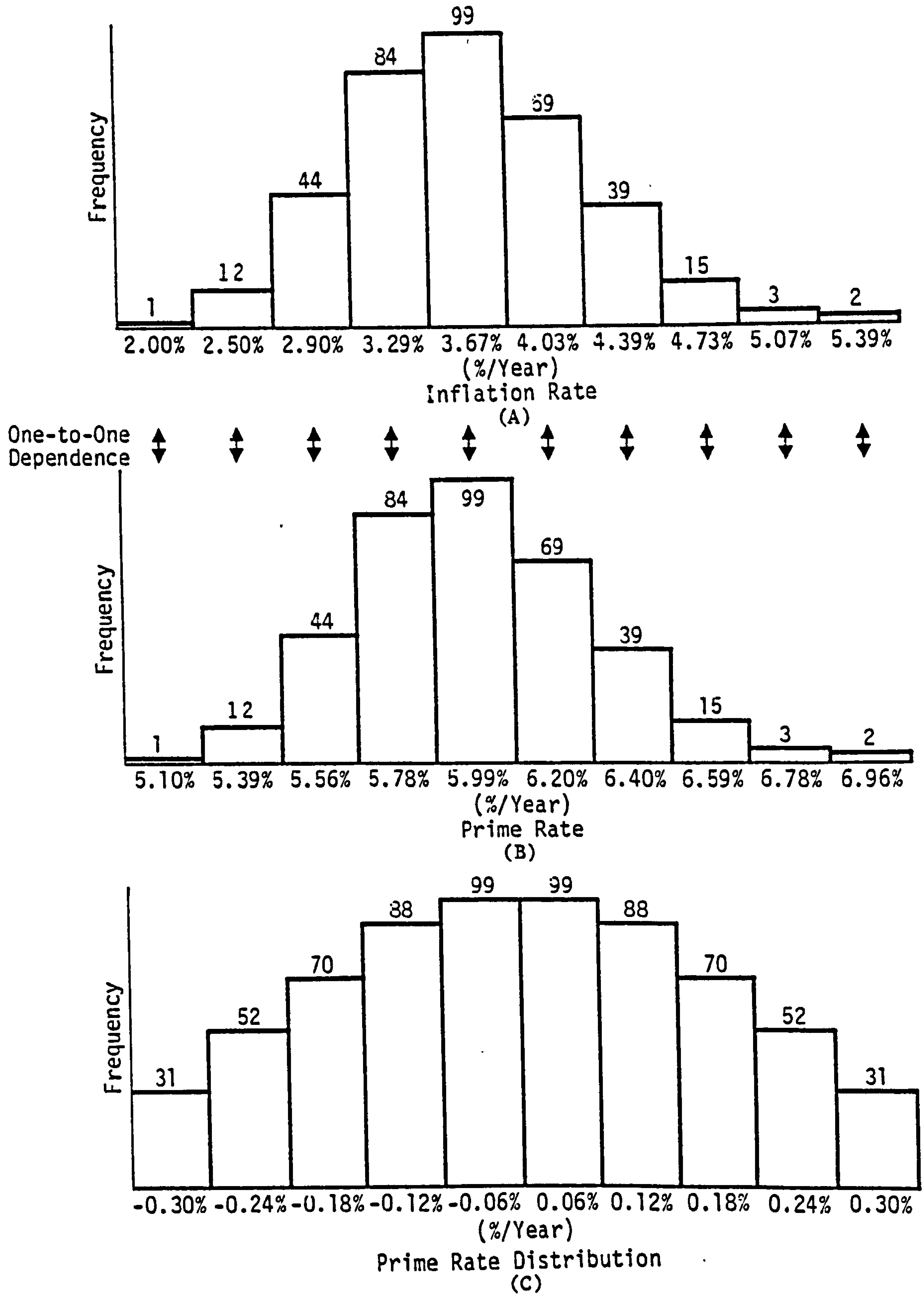


FIGURE 6-10
INFLATION, PRIME RATE, AND PRIME RATE DISTRIBUTION

The complete statistics are given in Table 6-6. The most-likely prime rate is I + ΔP. As Figures 6-10A and 6-10B indicate, there is a one-to-one correspondence between the selected inflation rate and the corresponding prime rate. This is randomly modified by the prime rate distribution (Figure 6-10C). Therefore, the actual prime rate used in the program is given by:

$$\text{Prime Rate} = I + \Delta P + PRD$$

where

I + ΔP is given in the Prime Rate (Figure 6-10B) and

PRD is given in the Prime Rate Distribution (Figure 6-10C).

6.3.2.3 Traffic Build Up

Local service airlines were contacted to find out how traffic builds up on their routes. Three airlines responded and the results are shown in Table 6-7. The airlines all indicated that their answers were opinions and were not the result of extensive research. The questionnaire was constructed in such a way that the data could be used to develop a model of the form:

$$D(t) = 1 - \alpha e^{-\beta t}$$

where

D(t) is the fraction of mature demand in period t,

t is the number of time periods since service was initiated on the route (six time periods per year),

α is the initial traffic deficit (Figure 6-11A), and

β is the traffic build-up rate (Figure 6-11B).

The coefficients (α, β) were chosen to approximate a weighted mean between new routes (Baker-LaGrande, Corvallis-Albany, and Roseburg) and suspension/replacement routes (Klamath Falls, North Bend-Coos Bay, Pendleton, Redmond-Bend, and Salem). Another study[9] found that third-level airlines generated an average of 75% of mature demand over all their routes the first year. This was consistent with the data from the local service carriers. The weighted build-up profiles yield 79.7% of mature demand in the first year, when the rate of aircraft acquisition is included.

6.3.2.4 Reliability Build Up

Reliability was found to be extremely important to traffic generation. Third-level operators were queried on the mechanical reliability of new equipment (emphasis was placed on those operators having Swearingen Metro IIs). The consensus was, with airframe and engine factory representatives in-house, that at the time of the start of scheduled flights the reliability would be 95% of maturity building to

TABLE 6-6

PRIME RATE VERSUS INFLATION MODEL

LINEAR REGRESSION OF THE DIFFERENCE BETWEEN THE PRIME RATE AND THE INFLATION RATE (%) AGAINST THE INFLATION RATE (%).

CORRELATION COEFFICIENTS

```
 1.000 -0.758
-0.758  1.000
ORIGINAL VALUES
 MULTIPLE REGRESSION    N=  39    M=   2
 VARIABLE    MEAN       ST.DEV.      CORREL.      REG.CO.    S.E. OF R.C. COMP. T
    2      5.74615      2.64448     -0.75823     -0.43998      0.06220     -7.07387
 DEPENDENT
    1      1.41000      1.53477
 INTERCEPT  3.93820   MULTIPLE CORRELN.  0.75823   S.E. OF ESTIMATE  1.01409
 ANALYSIS OF VARIATION           DF         SUM SQ       MEAN SQS.        F VALUE
ATTRIB. TO REGRESSION             1       51.45952       51.45952       50.03964
DEVIATION FROM REGRESSION        37       38.04938        1.02838
CORR. MULT. CORRELN.     0.75823
AUTO-CORRELN. OF RES. -0.11914
VON NEUMANN RATIO        2.30670
HETEROSCEDASTIC CORRELN. -0.08359
HETEROSCEDASTIC T-COMP.  -0.51022
```

NO.	OBS.Y	EST.Y	RESIDUAL
1	0.71000	1.83069	-1.12069
2	3.51000	2.89545	0.61455
3	2.26000	2.29267	-0.03267
4	3.33000	2.88665	0.44335
5	4.01000	3.28263	0.72737
6	1.57000	2.20907	-0.63907
7	1.06000	1.88349	-0.82349
8	0.76000	1.63270	-0.87270
9	1.69000	1.86589	-0.17589
10	2.73000	2.28827	0.44173
11	0.61000	1.42151	-0.81151
12	2.66000	2.00228	0.65772
13	2.46000	1.61510	0.84490
14	2.08000	1.11352	0.96648
15	3.46000	1.72069	1.73931
16	2.31000	1.23232	1.07768
17	3.01000	1.74269	1.26731
18	4.26000	2.31027	1.94973
19	1.67000	1.49190	0.17810
20	-0.33000	1.21032	-1.54032
21	-0.35000	1.40391	-1.75391
22	2.59000	2.45106	0.13894
23	2.06000	2.36747	-0.30747
24	-0.89000	1.39071	-2.28071
25	2.18000	2.69745	-0.51745
26	1.92000	2.43347	-0.51347
27	1.09000	1.88349	-0.79349
28	-0.35000	1.09592	-1.44592
29	-0.13000	0.78353	-0.91353
30	1.72000	0.67794	1.04206
31	0.99000	0.05756	0.93244
32	-0.51000	-0.36042	-0.14958
33	0.90000	-0.47921	1.37921
34	-0.53000	-1.57037	1.04037
35	-2.37000	-1.94435	-0.42565
36	-1.03000	-0.43801	-0.59199
37	2.31000	1.95389	0.35611
38	0.59000	0.87153	-0.28153
39	0.53000	0.83633	-0.30633

TABLE 6-7

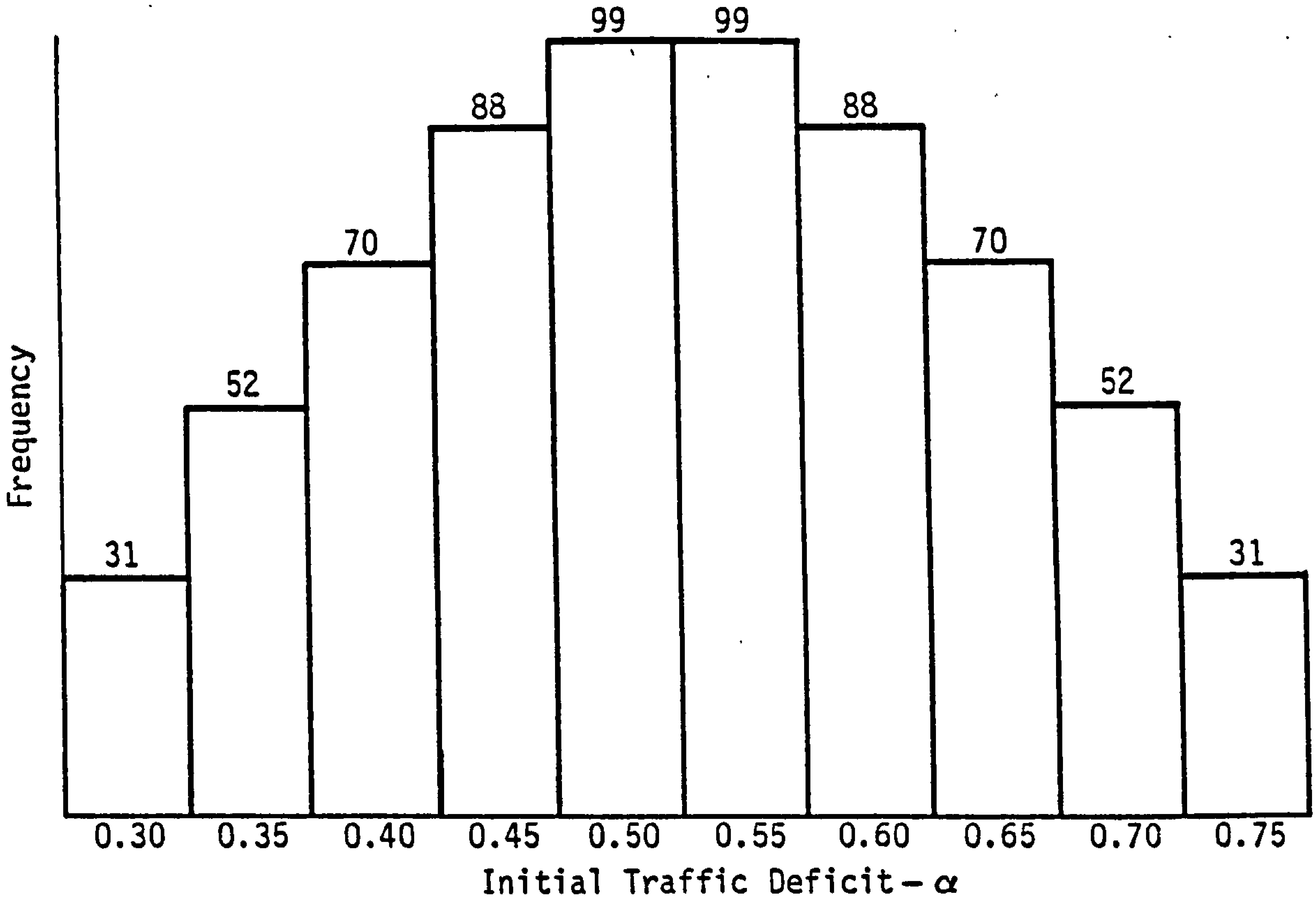
TRAFFIC BUILD UP ON AIRLINE ROUTES

Route Type	Mean % of Mature Demand	Range of Mature Demand	Mean Time to Maturity	Range of Times to Maturity
New Route[1]	55%	10-90%	16 mos.	3-36 mos.
Suspension/ Replacement[2]	90%	50-100%	2 mos.	0-24 mos.
Competitive[3]	80%	50-100%	11 mos.	1-24 mos.

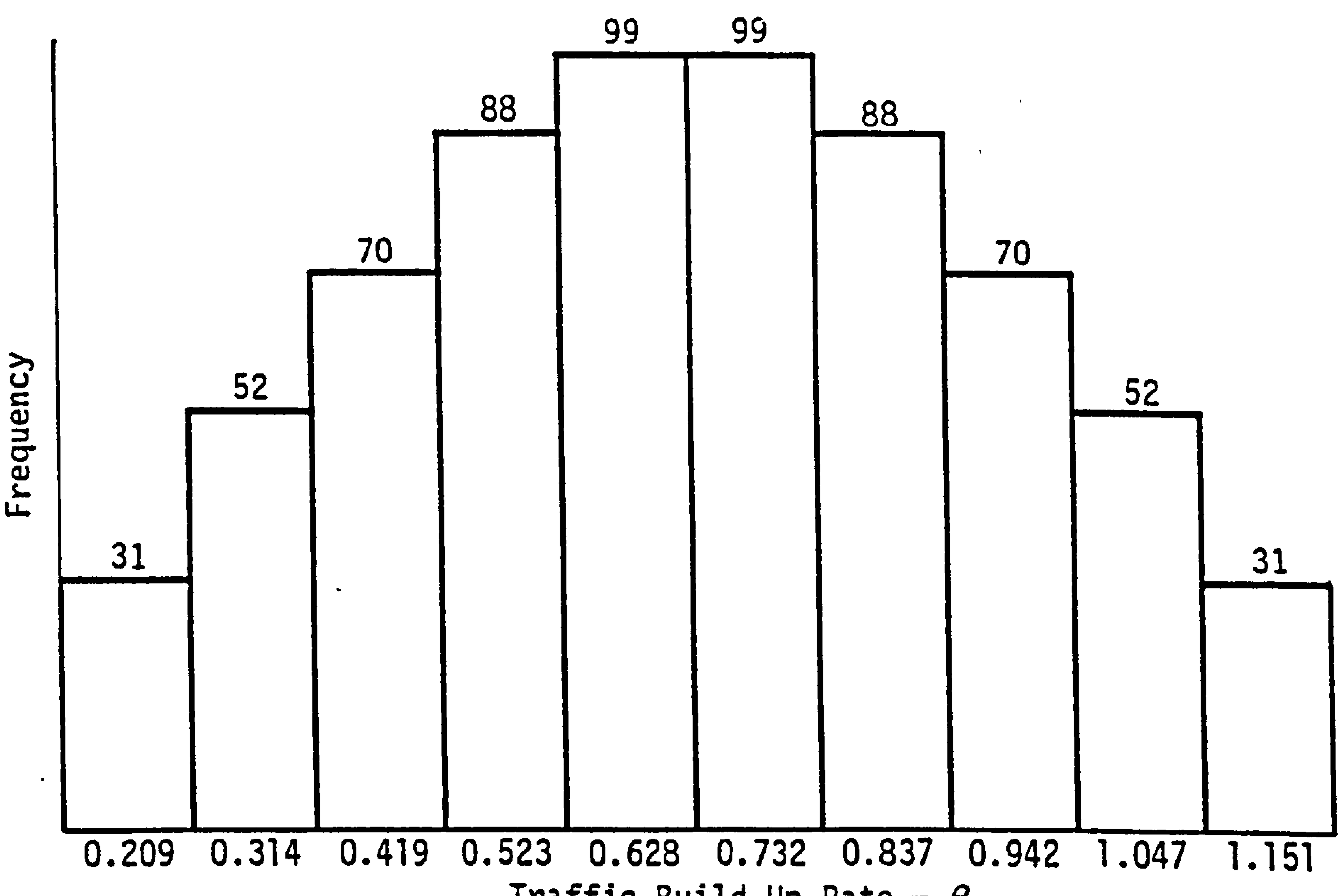
1 No air service on the route for at least six months, respondent initiates service.

2 Another carrier has suspended service on the route and respondent replaced the other carrier within six months.

3 Another carrier is providing service on route and respondent enters the market.



(A)



(B)

FIGURE 6-11
INITIAL TRAFFIC BUILD-UP FACTORS

99% of maturity in one year. The simulation equation had the form:

$$RF(t) = (1 - \omega e^{-t/3})^{\kappa}$$

where

RF(t) is the traffic factor

ω is the mechanical reliability deficit (Figure 6-12),

t is the time period (six time periods per year), and

κ (2.27366) is the sensitivity of traffic to reliability (Table 4-6).

Figure 6-13 shows the build up of travel demand including mean traffic build up and mechanical reliability, but excluding aircraft acquisition rate (three per time period, eight needed to initiate full service in the third time period), annual growth, and the effect of seasonal traffic fluctuations.

When the rate of aircraft acquisition is included, the first year's traffic is 72.2% of maturity.

6.3.2.5 Seasonal Traffic Fluctuations

Monthly data from Hughes Airwest for the years 1969 and 1975 was analyzed to determine how demand varied on a seasonal basis. First, the month-by-month totals for all stations were computed. Next, the effects of annual growth were removed (Section 5.3.3.2.3). Then, the fraction of mean monthly traffic per month was computed. Lastly, bimonthly groups had to be developed. The bimonthly groups had to be developed such that the first group of the simulation most nearly approximated the mean of all groups. This last step was supposed to be unnecessary according to the PROSPER manuals. The PROSPER manuals said that PROSPER added the seasonal values, found the mean, and divided each value by the mean to get the relative values. In debugging the PROSPER program, it was discovered that PROSPER took the first value as the mean and ratioed all others to that value. This prevented using PROSPER directly to find the best time of the year to start the airline. This was computed later, by other means, at less computational expense. The seasonal traffic fluctuations are shown in Figure 6-14; the December-January time period is the mean of all fluctuations.

6.3.2.6 Aircraft

The build up and likelihood of aircraft in service, cost of the aircraft, and aircraft residual value are shown in Figure 6-15. The payments for aircraft begin three time periods (six months) before the aircraft can be placed in service. When the airline is fully equipped with aircraft there is a 25% chance it will require 10 aircraft, a 50% chance it will require 11 aircraft, and a 25% chance it will require 12 aircraft.

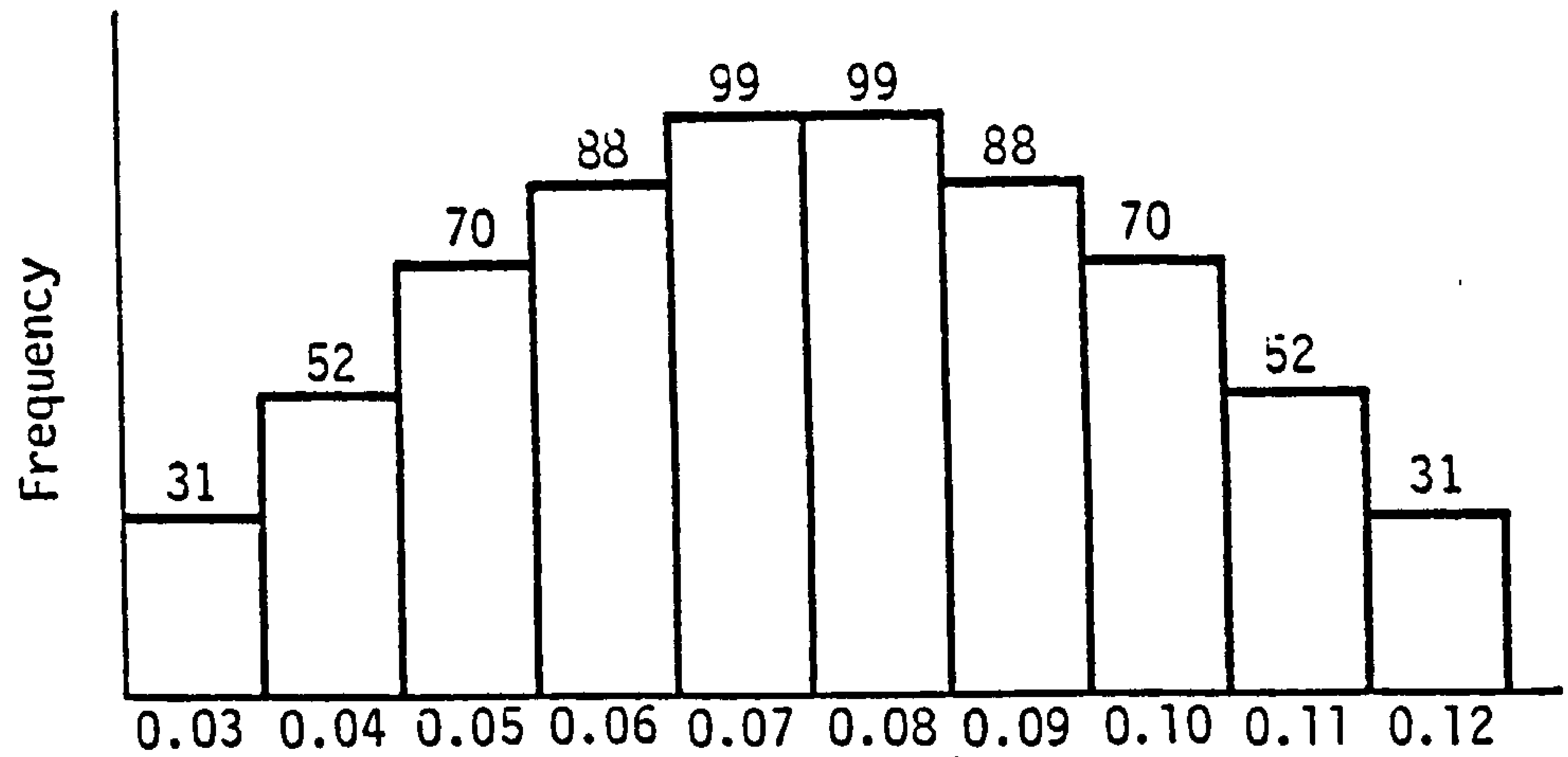
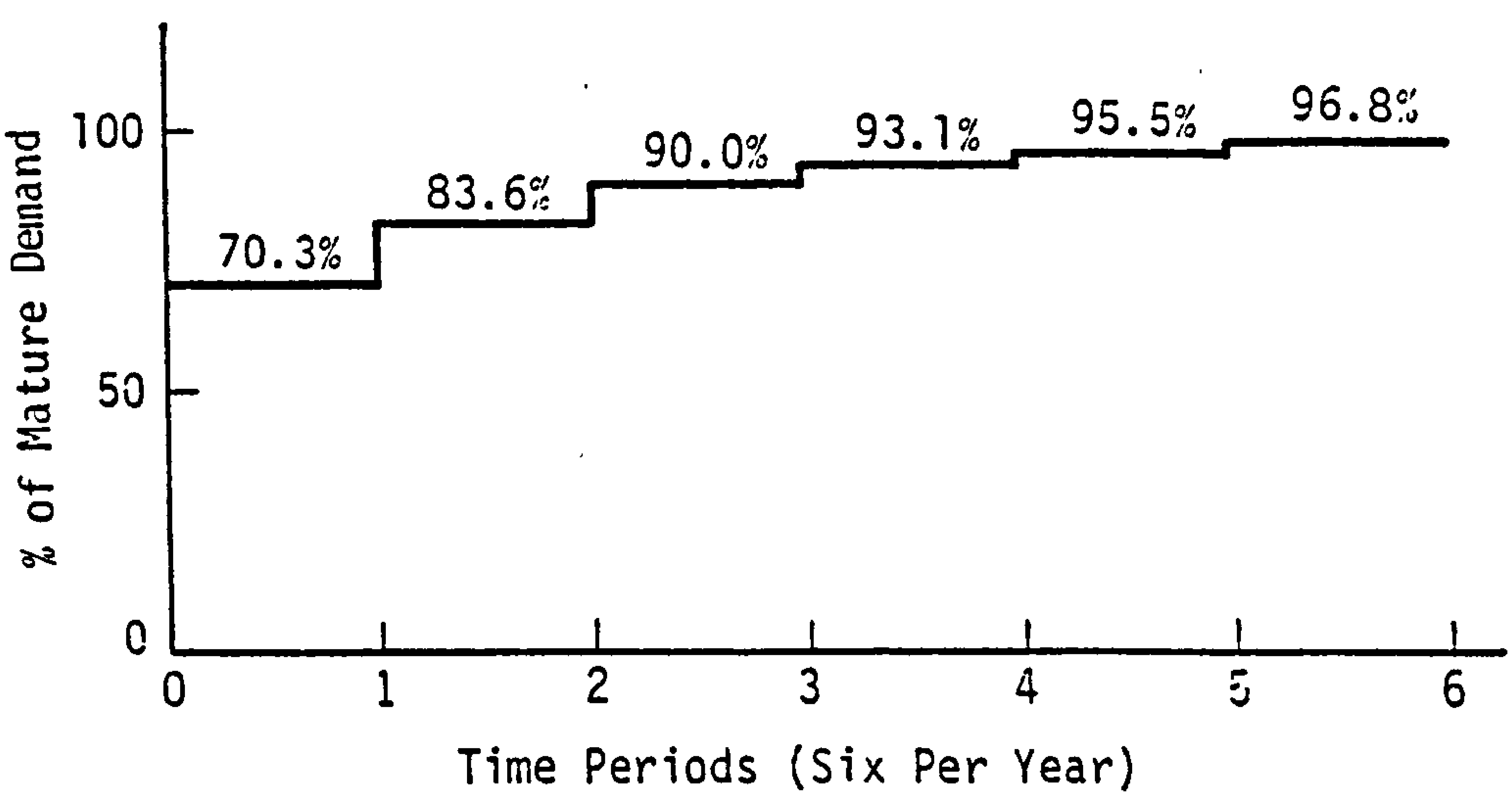


FIGURE 6-12
MECHANICAL RELIABILITY DEFICIT–ω



(excluding seasonal fluctuations and aircraft acquisition rate)

FIGURE 6-13
MEAN DEMAND BUILD UP

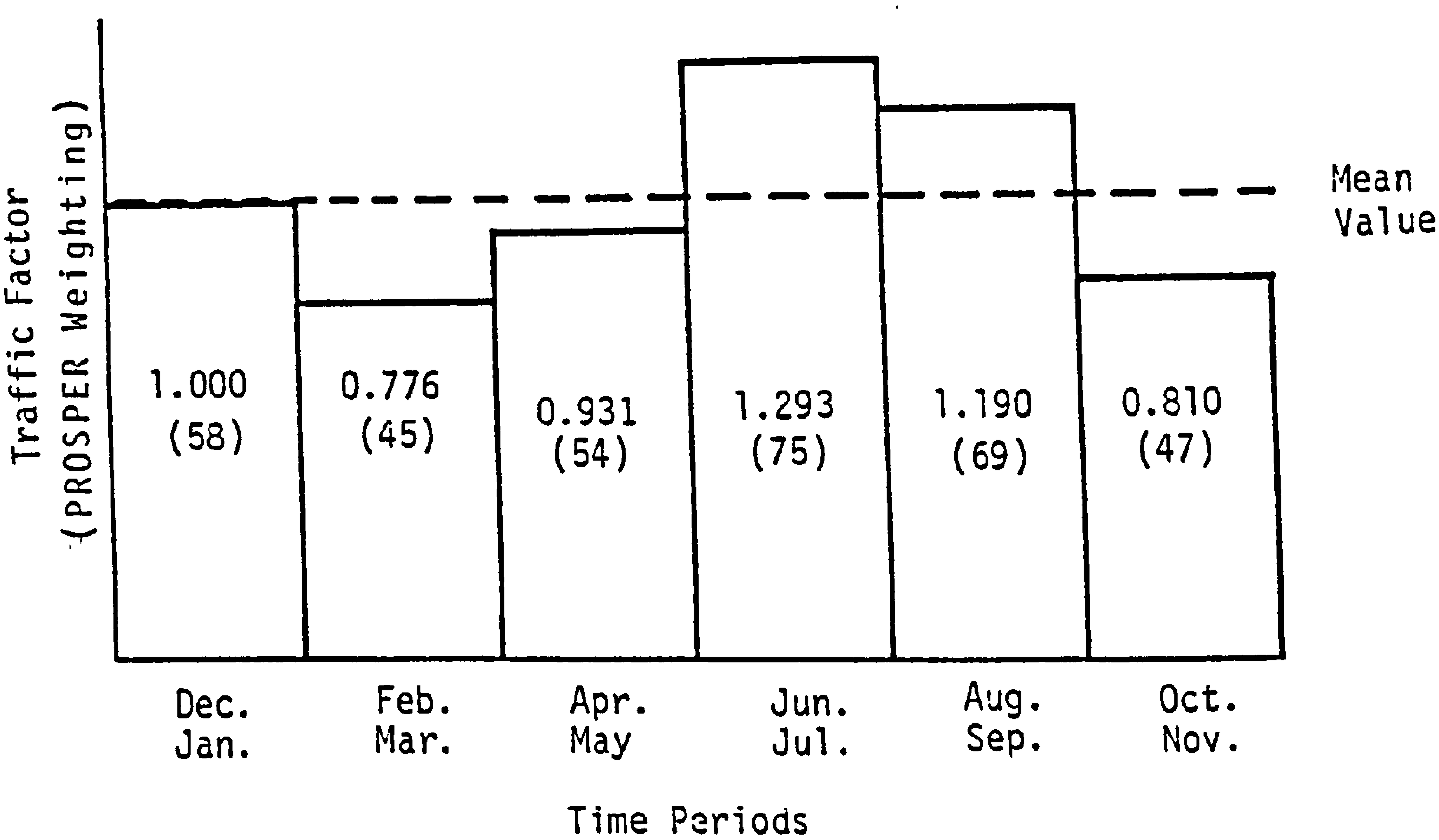
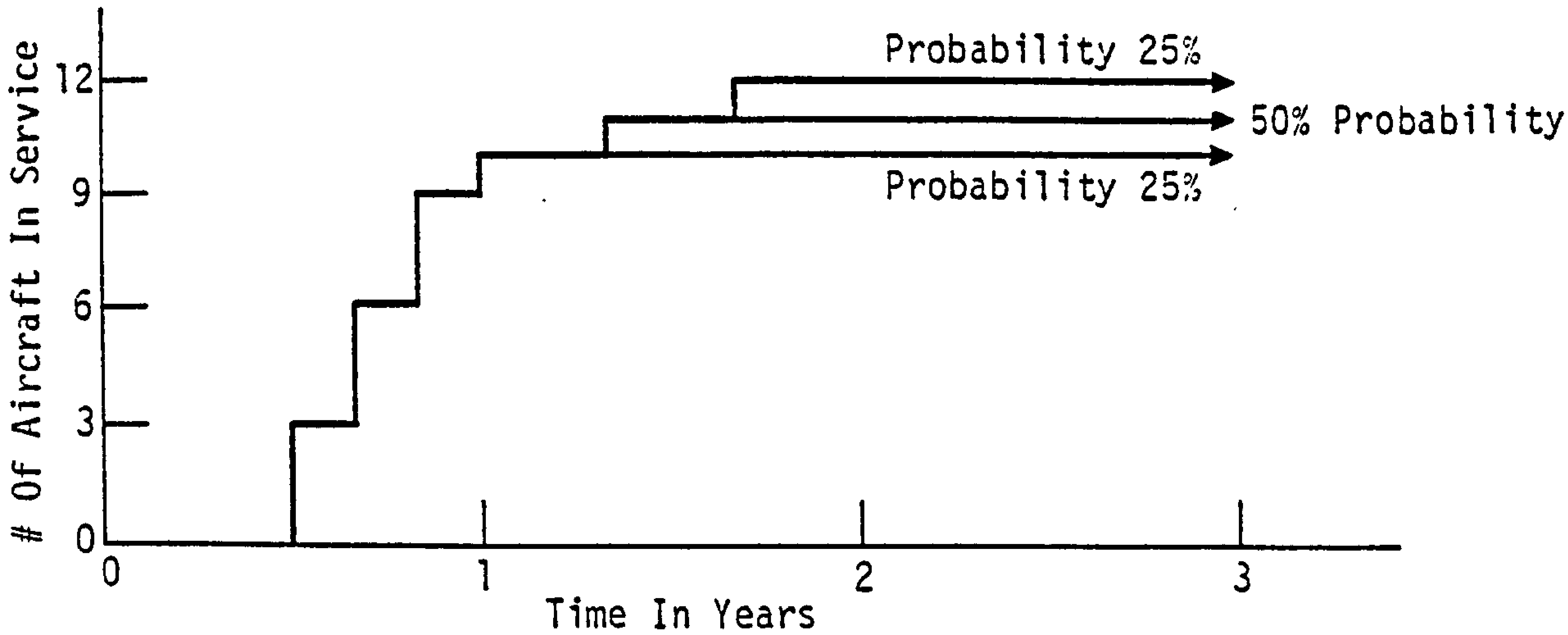
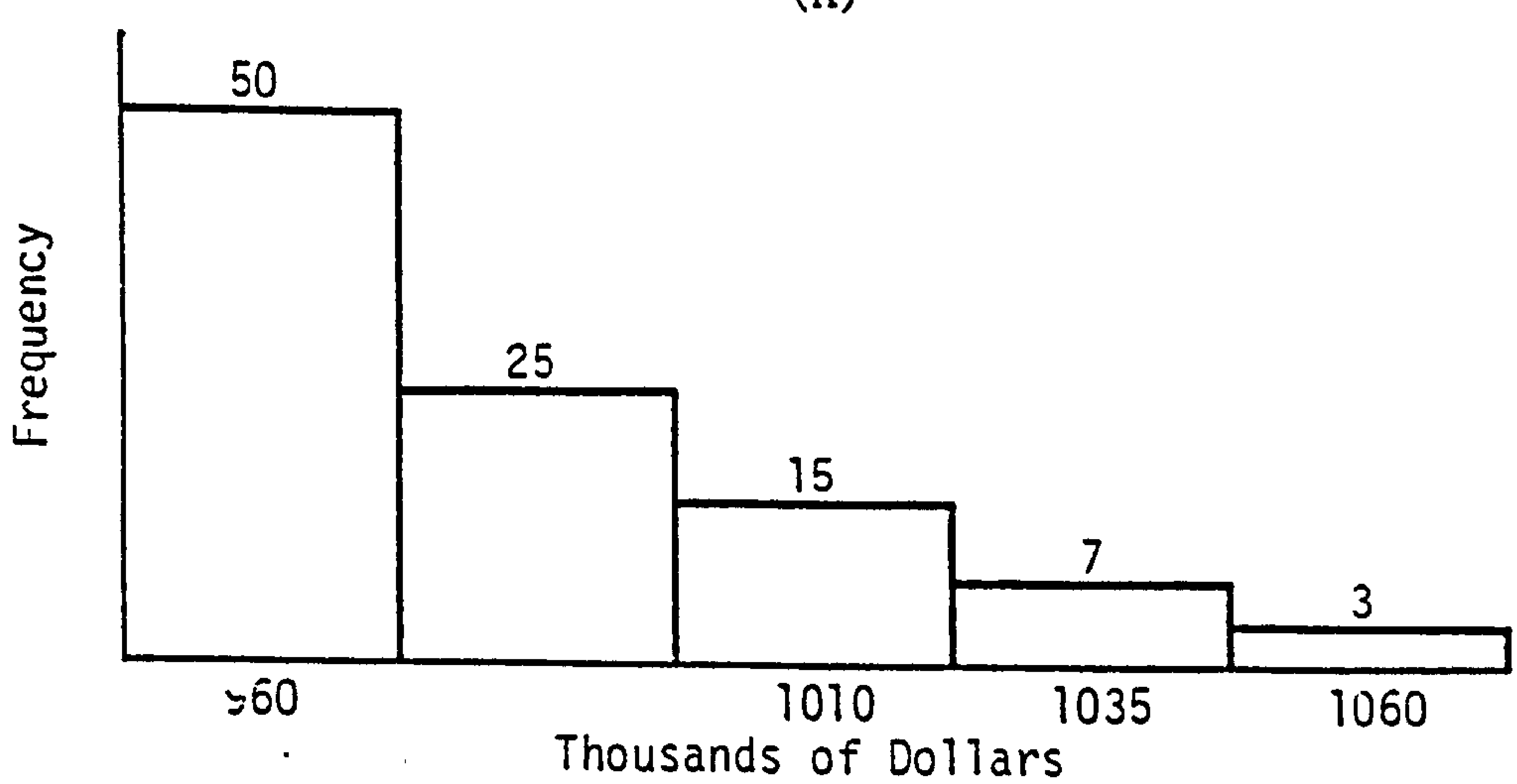


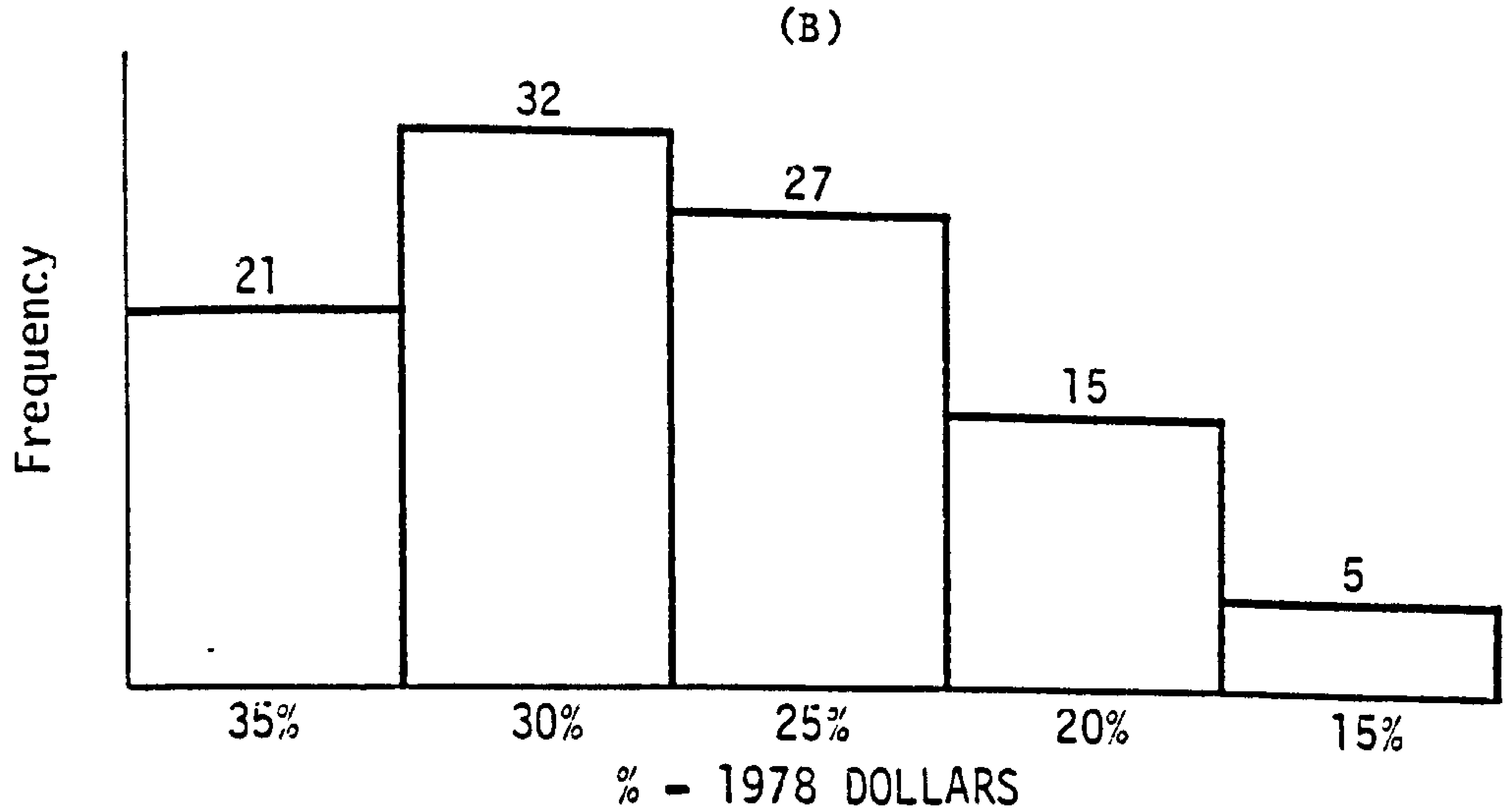
FIGURE 6-14
SEASONAL TRAFFIC FLUCTUATIONS



Aircraft in Service
(A)



Aircraft Cost
(B)



Aircraft Residual Value
(C)

FIGURE 6-15
AIRCRAFT

Aircraft cost was based on the most-likely cost in six months. With a cost of $960000 now (Table 3-3) and six percent inflation and the real cost of aircraft already in production falling 1.5% per year the most-likely cost is up 2.2%; therefore, the mean of the distribution is fixed at $980200. The shape of the distribution is a result of discussions with the manufacturer.

The likely aircraft residuals, which are only applicable in the aircraft purchase or tax shelter scenarios, were determined from data for the Metro II and similar aircraft from the Aircraft Blue Book.[46] The residuals were converted to their 1987 value and the difference between this value and 15% of the purchase price was taxed at the capital gains rate (50%) when the aircraft were sold.

6.3.2.6.1 Aircraft Financial Terms

The financial terms assumed are representative of what the third-level industry is currently receiving from the financial community.

Debt Financing--20% down with 80% financed over seven years at prime plus 2%. A 1% deposit is required by the bank for the 6 months between aircraft order and aircraft delivery. The margin is assumed to be 2%. The margin over prime usually averages 1-4%, but some operators have been charged as high as 8%. Two percent was chosen because the cash reserves planned were well above average. These financing assumptions were also used for the tax shelter model. Depreciation, for tax purposes, was over seven years by the sum-of-the-years'-digits method to a 15% residual.

Lease with ITC retained by the Airline--prime plus 3.25% over a ten year period, payment for the first month in advance, and a 10% (of aircraft purchase price) deposit held for 30 months at 4.5% per annum. The airline retains the investment tax credit. This is the most common third-level airline lease.

Lease without ITC--Prime minus 2% over a ten year period, payment for the first month in advance, and a 10% (of aircraft purchase price) deposit held for 30 months at 4.5% per annum. The airline has exchanged its ITC for a further reduction in the lease rate.

6.3.2.7 Engine Spares

The probability distributions for engine spares are shown in Figure 6-16. These distributions are based on the engine simulations in Section 4.4.4. The timings are modified to conform with estimates by the engine manufacturers, airframe manufacturers, and third-level airlines. Engine spares are purchased for 20% down with 80% financed over seven years at prime plus 2%. They were depreciated over seven years by the sum-of-the-years'-digits method to 15% of their purchase price in 1978, and sold at 15% of their inflated purchase price in 1987, capital gains being paid on the difference.

6.3.2.8 Airframe and Systems Spares

These spares include all aircraft spares except engines. It was

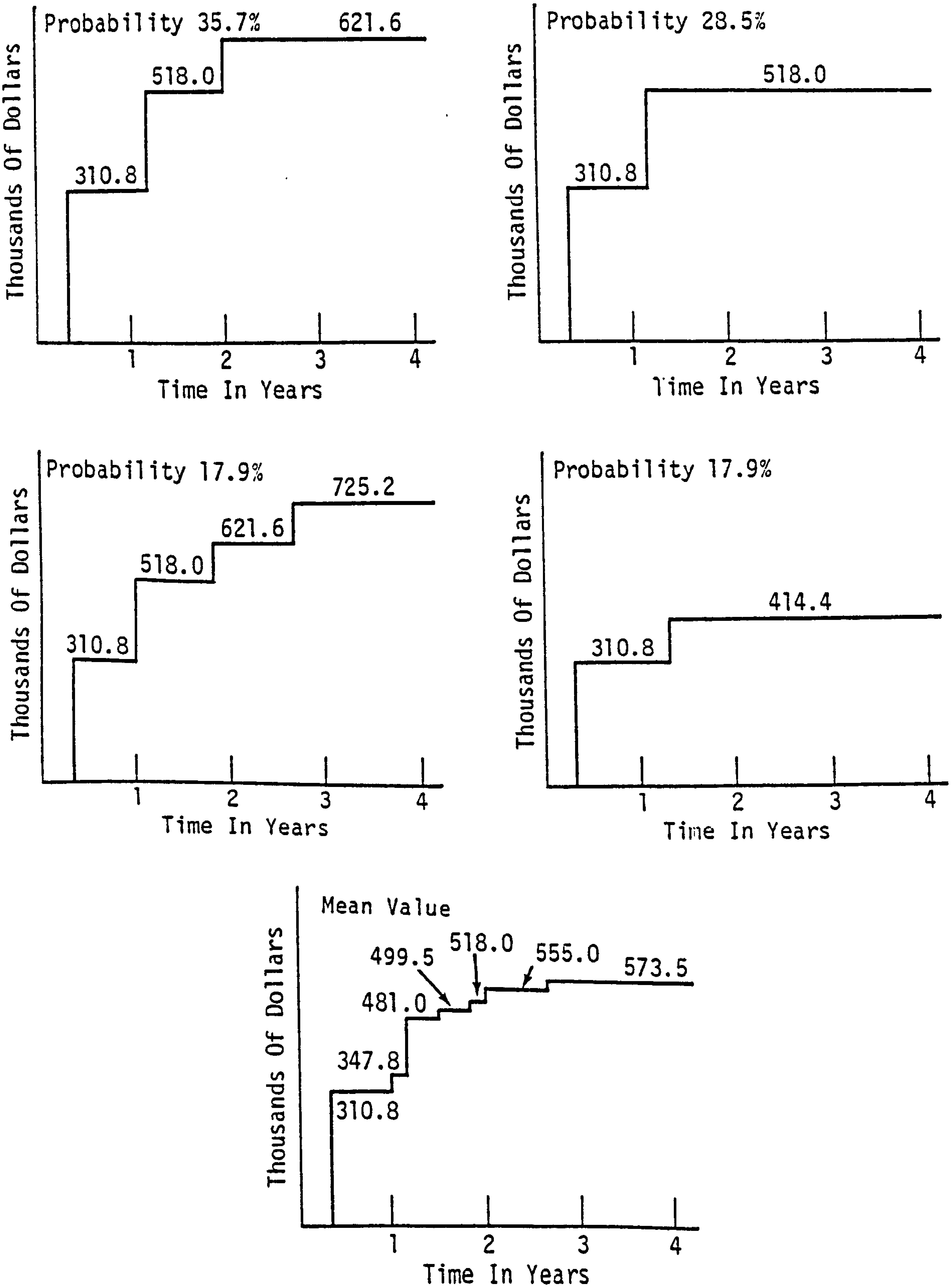


FIGURE 6-16
ENGINE SPARES

difficult to envisage a spares value less than $267000, with $107000 of avionics spares and Swearingen recommending $80000 plus $8000 per aircraft for spares (minimum of 10 aircraft), but values below this were included at low probabilities because spares could be consumed and a lower service level maintained, i.e., spares could be used instead of airframe material to reach a new, more appropriate service level.

The average of the curve is $282700, 3% above the recommended level for eleven aircraft, allowing for some accumulation and obsolescence. Figure 6-17A shows the airframe and systems spares value, and Figure 6-17B shows the spares build-up rate. The spares build up is taken from Table 4-3.

Spares were purchased for 20% down with 80% financed over seven years at prime plus 2%. They were depreciated over seven years by the sum-of-the-years'-digits method to 15% of their purchase price in 1978, and sold at 15% of their inflated purchase price in 1987, capital gains being paid on the difference.

6.3.2.9 Hangar And Offices

Figure 6-18 was developed by assuming hangar and office space was normally distributed between 13500 and 15800 square feet (Section 4.1.2.1), and that construction cost was normally distributed between 18 and 24 dollars per square foot, as developed during the third-level airline survey. The hangar and office were purchased for 10% down with 90% financed over 16.5 years (20 years would have been preferred, but PROSPER was limited to 99 time periods). It was depreciated by the sum-of-the-years'-digits method over 20 years to a 10% residual. At ten years its residual value was 27.94% (1978 dollars) it was sold for 50% of its 1987 value, capital gains being paid on the difference.

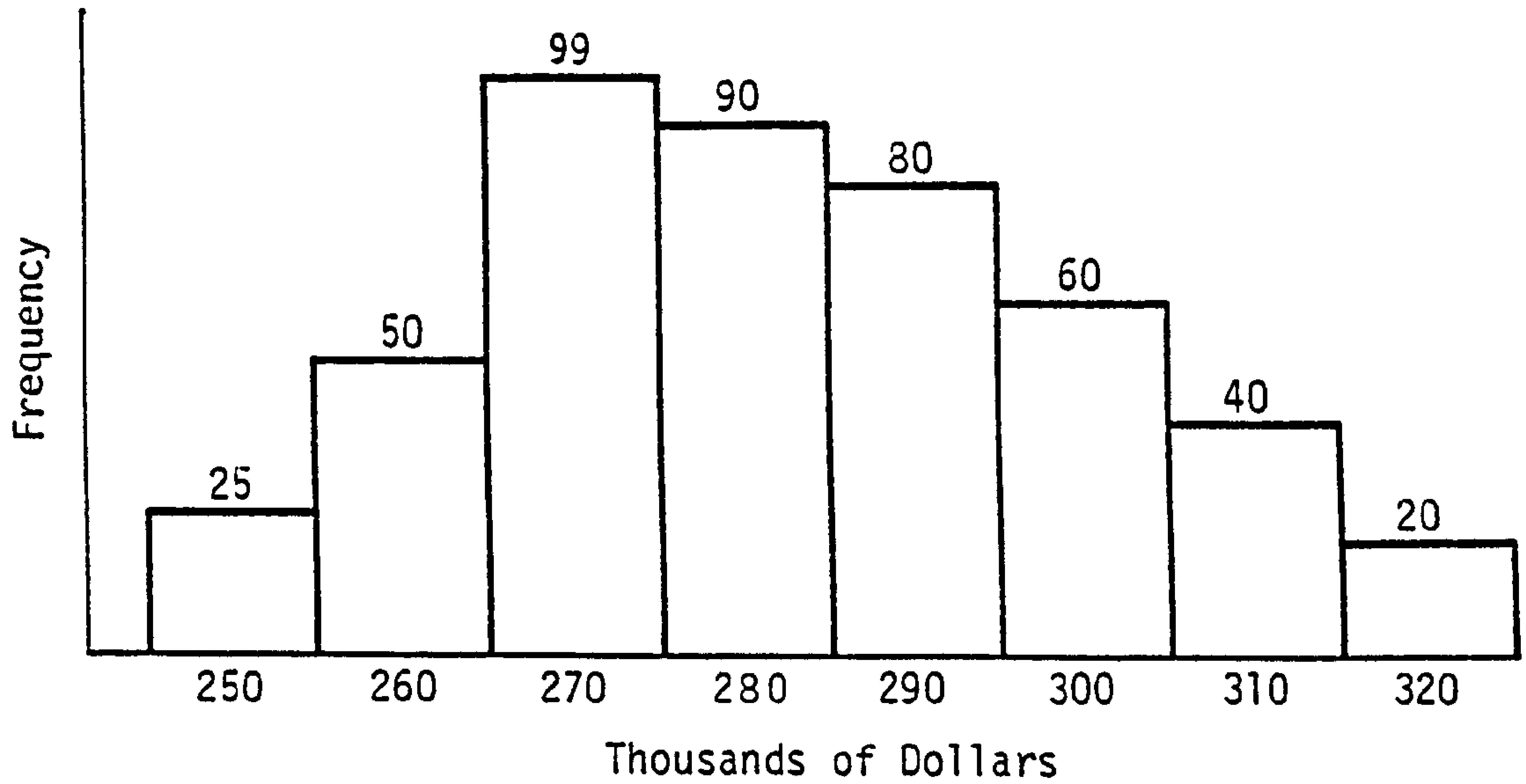
6.3.2.10 Shop and Office Equipment

Shop and office equipment includes general shop equipment ($73000), Metro II special tools ($28000), engine equipment ($54000), and office equipment ($50000). Station equipment cost was determined from a survey of third-level operators, $20000 at Portland and Medford, and $2000 at Baker-LaGrande, Corvallis-Albany, Klamath Falls, North Bend-Coos Bay, Pendleton, Redmond-Bend, Roseburg, and Salem, for a total of $56000. The total of all shop and office equipment was $261000 and the distribution is shown in Figure 6-19.

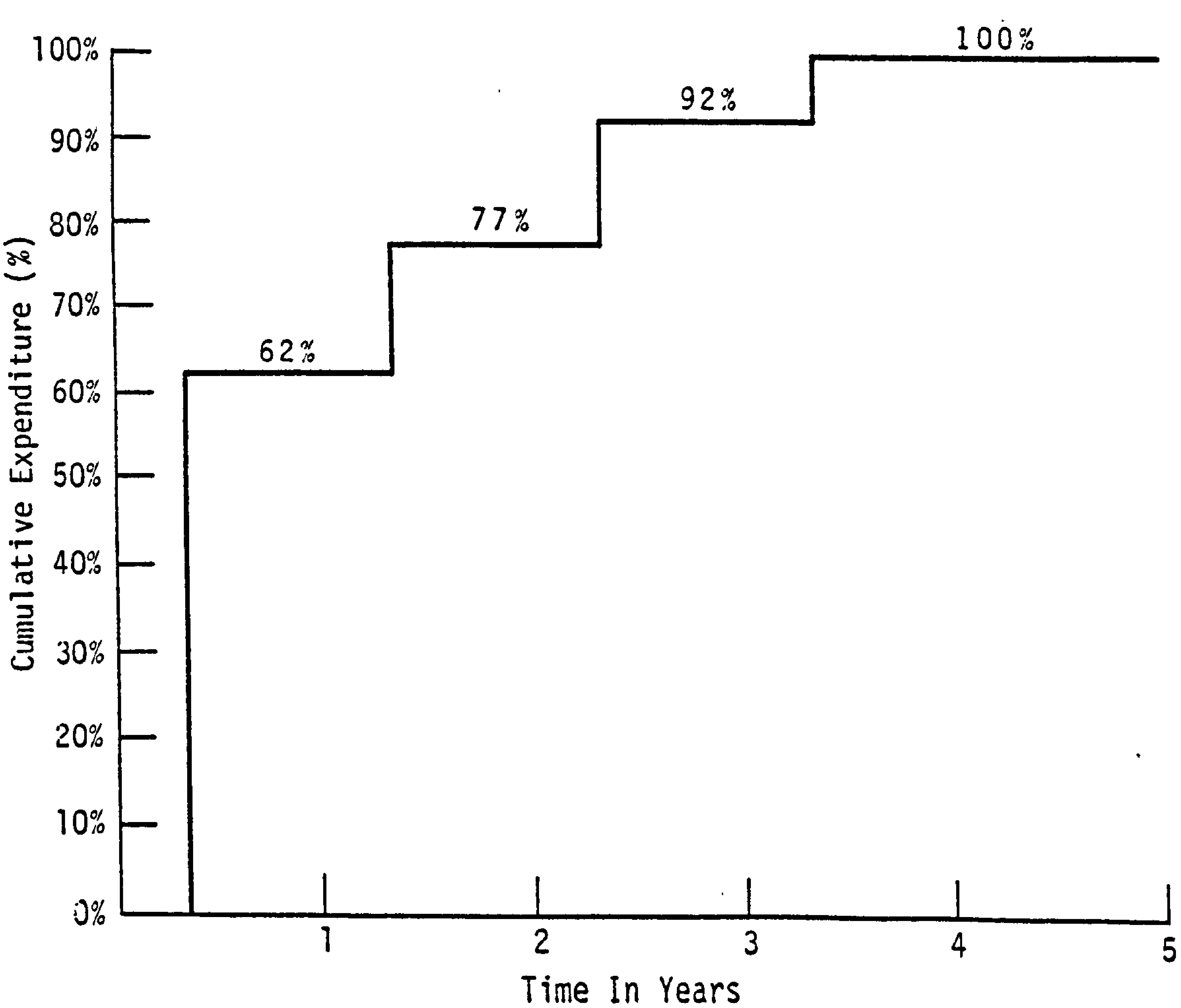
Shop and office equipment was purchased for 20% down with 80% financed over seven years at prime plus 2%. It was depreciated over seven years by the sum-of-the-years'-digits method to 15% of its purchase price in 1978 and sold at 15% of its inflated purchase price in 1987, capital gains being paid on the difference.

6.3.2.11 Initial Advertising

For a third-level airline just commencing operations, the advertising budget is usually the first fund robbed when unexpected expenses occur. The third-level airlines surveyed all indicated that initially their investment in advertising had been minimal, but that now



(A)



(B)

FIGURE 6-17
AIRFRAME AND SYSTEM SPARES

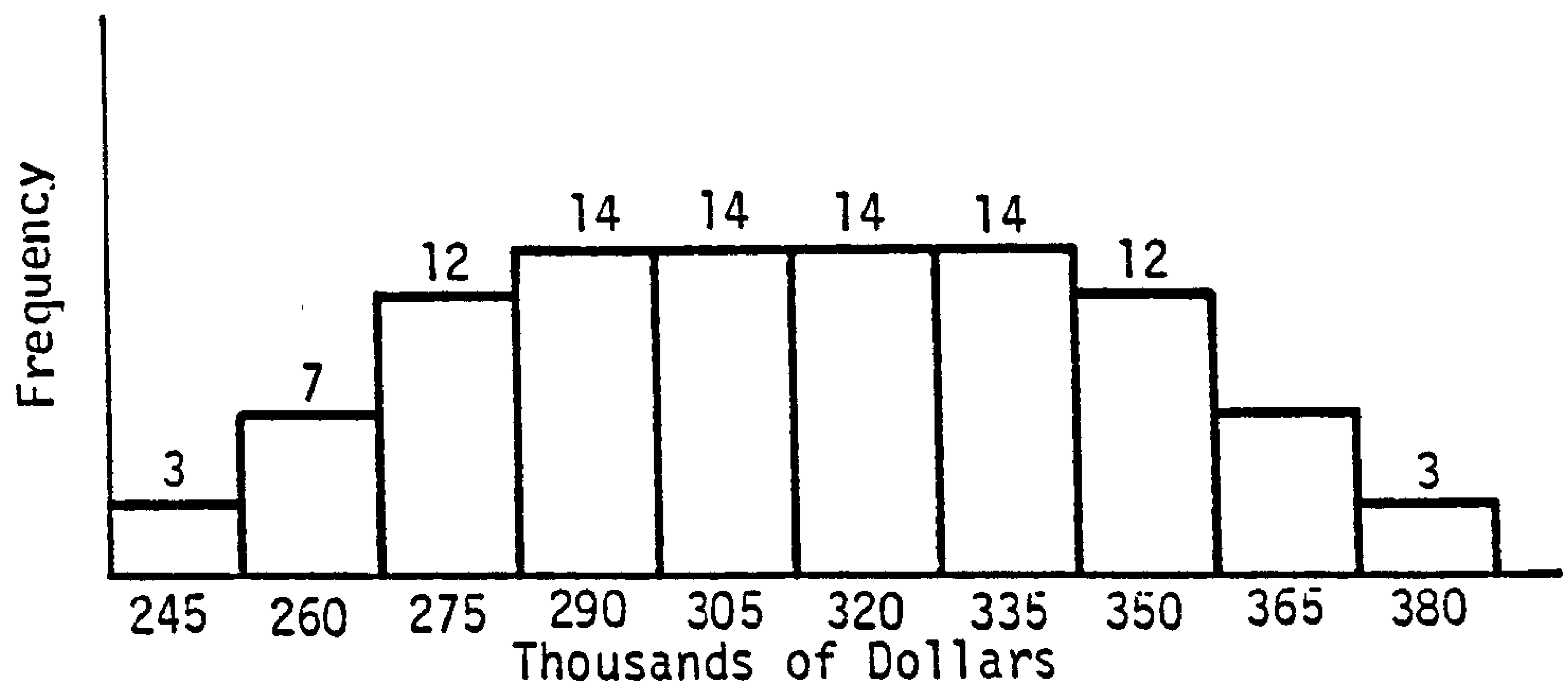


FIGURE 6-18
HANGAR AND OFFICE COST

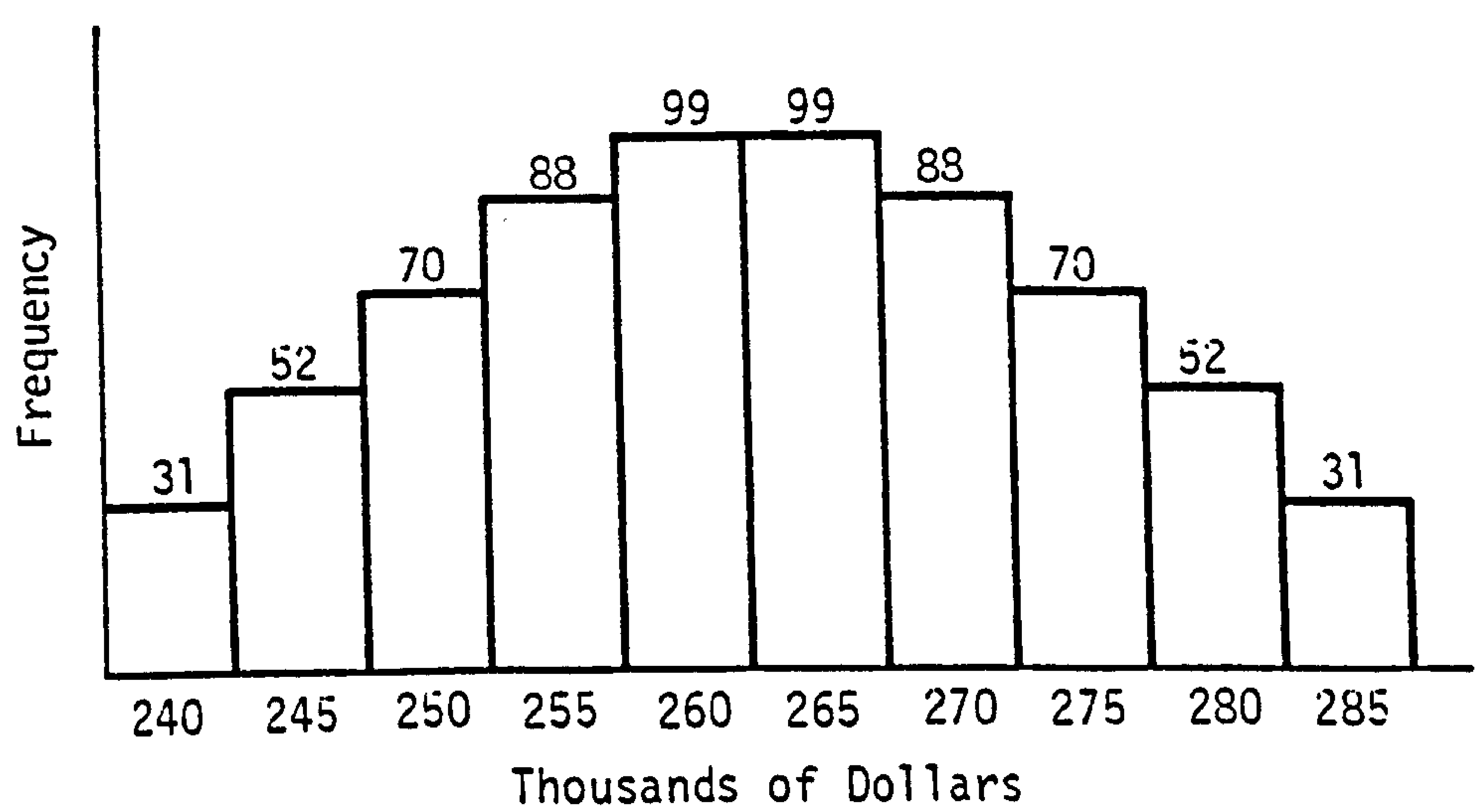


FIGURE 6-19
SHOP AND OFFICE EQUIPMENT

investment averaged between 2.5% and 3.5% of revenue. Operators indicated they would now invest approximately a year's worth of advertising during the start-up period alone. Local service carriers were surveyed (four respondents) to determine the timing of the initial advertising campaign. They indicated the initial advertising campaign should begin from one to eight weeks before commencing revenue flights, with an average of three weeks. The initial advertising should continue from one to sixteen weeks after the revenue flights start, with an average of six weeks.

Initial advertising expense probabilities are shown in Figure 6-20. The six annual periods of PROSPER necessitate that ads be placed two months before the initial route is begun, and continue until two months after the last route is begun.

6.3.2.12 Taxes

The tax schedule for Oregon is shown in Table 6-8. The local, state, and federal aircraft and property taxes are assumed included in indirect operating costs--nonlabor, and the fuel tax is included in the direct operating cost equation for fuel; federal and state corporate excise taxes, capital gains tax, and investment tax credit are considered explicitly in the PROSPER program.

6.3.2.13 Wind Up at Ten Years

Equipment was sold, balance due on leases and taxes paid, and capital gains taken in the last time period. All equipment and revenue production were assumed available until the last day.

6.3.2.14 Combination of Probability Distributions

The probability distributions of Section 6.2.4 (Table 6-5), and Sections 6.3.2.1 - 6.3.2.13 were combined in PROSPER to yield two new probability distributions, cumulative cashflow and net-present-value, for each financing scenario. The airline was simulated 1002 times over a ten-year time period. The cumulative-cashflow distributions will be used to determine cash required to start up the airline, and the net-present-value distributions to determine the proper method of financing aircraft.

6.3.3 Analysis of Cumulative Cashflows

A three-dimensional view of cumulative cashflow is shown in Figure 6-21. The probability/cumulative-cashflow plane contains the probability distribution of the minimum cumulative cashflows. The minimum cumulative-cashflow probability distribution may be analyzed to determine the optimum amount of cash to have available before start up to ensure the success of the operation. Three methods are used; the first is the most important, the last two being mainly for comparison.

6.3.3.1 Optimum Coverage Analysis

The first method is termed "optimum coverage analysis" and defines the logical, optimal amount of financal resources a project manager will want to have available before he undertakes a project.

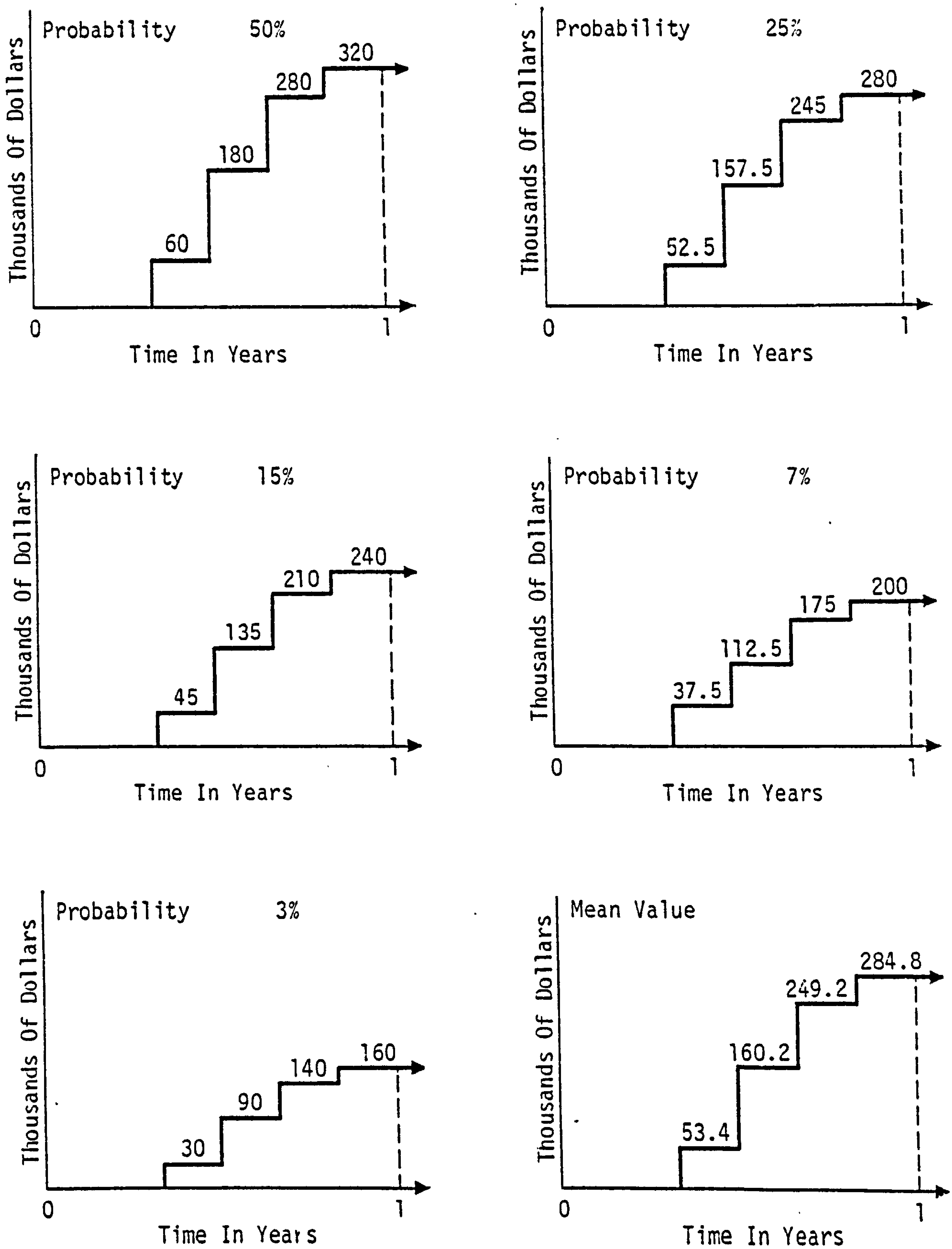


FIGURE 6-20
INITIAL ADVERTISING EXPENSES

TABLE 6-8

TAXES

GENERAL TAXES

Federal		Oregon		Local
Ticket Tax	8% of revenue	Property Tax (Aircraft & Fixed Property)	3% per year	Property tax at the county tax rate. Fixed property and equipment is taxed as property at 100% of true cash value.
Cargo	5% of revenue	Aircraft	$20 per year	Fuel: $0.00-$0.04 per U.S. gallon.
Aircraft	$25 + $0.035 (GTOW) per year	Pilots	$2 per year	
Biannual Registration	$15	Fuel	$0.07 per U.S. gallon	

CORPORATE TAXES

Federal	Oregon
20% First $25000 taxable income	7.5% of net income 1978
22% Second $25000 taxable income	8.0% of net income after 1978
48% Excess of $50000 taxable income	
50% Capital gains tax	

FEDERAL INVESTMENT TAX CREDIT (ITC)

The investment tax credit rate is 10% through 1980 at which time it reverts to 7%. Corporations may carry-back Investment Tax Credits (ITC) for three years and forward for seven years on a first-in, first-out basis. The credit may reduce 100% of the first $25000 of corporate income tax. Tax in excess of $25000 may be reduced 100% by airlines in 1977 and 1978, from tax year 1979 onwards the allowable reduction decreases by 10% per year until 1983 when the reduction in tax in excess of $25000 is limited to 50%, the perpetuity rate.

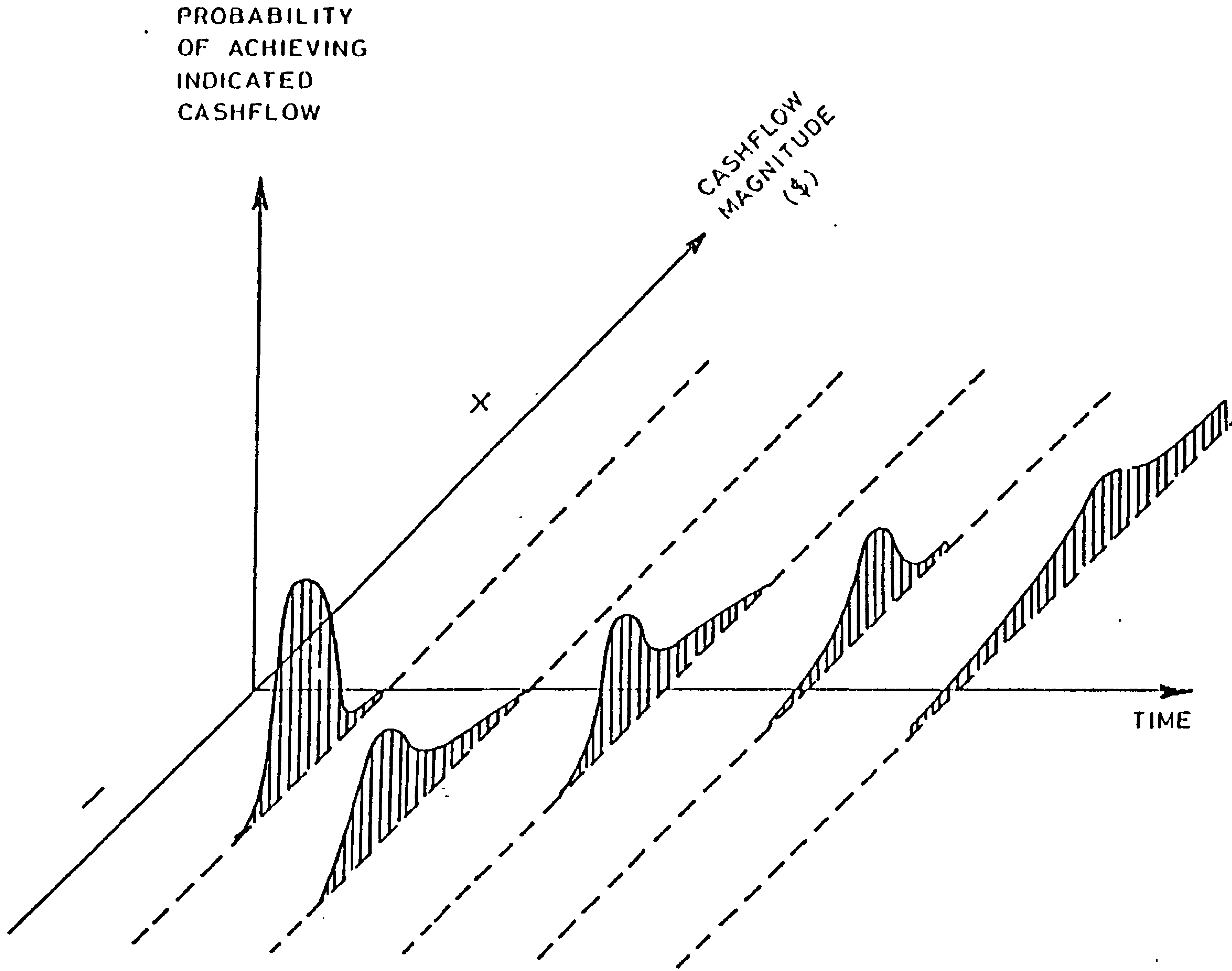


FIGURE 6-21
CUMULATIVE CASHFLOW PROBABILITY

Optimum coverage is best described by means of an example. Suppose a manager knows that with 50 dollars he has enough money to undertake a project and complete it successfully 50% of the time. But with 51 dollars, a 2% increase in investment, he can successfully complete the project 54% of the time. Then for a 2% increase in the investment he has achieved a 4% increase in the chance of success. Now suppose the manager continues incrementing the money available for investment, and analyzing the increase it provides to his chance of success, until at 80 dollars he adds one dollar which increases the investment 1.25% and, at the same time, his chance of success rises from 90% to 91.25%. This is the optimum coverage point--where the increment in investment equals the increment in chance of success. Taking the analysis one step further, the manager continues to increase the investment until at 100 dollars he adds a dollar and the investment increases 1% and the chance of success increases from 98% to 98.6% This is a poor exchange of increased investment for increased chance of success. Expressed mathematically, optimum coverage occurs where:

$$P'(I) = \frac{1}{I}$$

where

P'(I) is the slope of the probability density function at investment level I, and

I is the level of investment.

This implies that not only a mathematical, but a graphical solution exists (Figure 6-22).

Figure 6-23 illustrates how optimum coverage varies with the shape of the probability distribution and the investment required. Three probability density functions are shown. The first is a normal distribution with both the mean and standard deviation equal to one ($\mu = \sigma = 1$); this defines its shape, but does not define its position relative to the zero cumulative-cashflow point. The second is a Poisson distribution with the same mean and standard deviation. The last distribution is a mirror image of the Poisson distribution, and it has the same mean and standard deviation as the other two distributions.

The steeper the slope of the probability density function the greater the investment required to achieve optimum coverage (Mirror-of-Poisson to Normal to Poisson), but the actual increase in investment (Poisson to Normal, 8.7%; Normal to Mirror-of-Poisson, 3.8%) is less than the percentage increase in coverage (Poisson to Normal, 7.5%; Normal to Mirror-of-Poisson, 8.2%). Poisson to Normal is slightly less because of round-off errors; the cumulative-cashflow axis (abscissa) was limited to two hundred points.

When the mean-investment required is increased by 25% the optimum coverage point and the subsequent investment required increases more than 25% because there is now more money to protect (the absolute and percentage increase in investment is inversely proportional to the

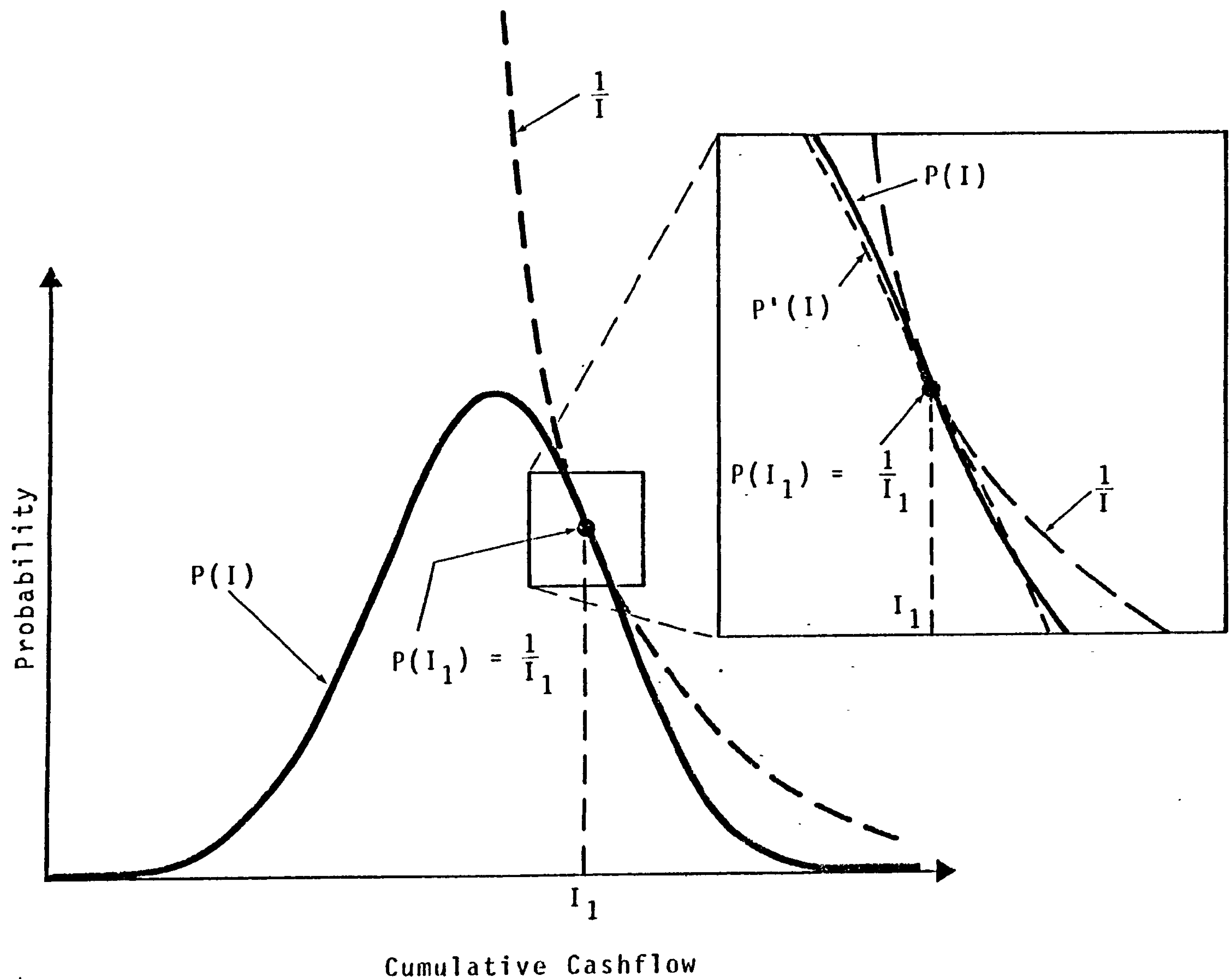


FIGURE 6-22
DETERMINING THE OPTIMUM COVERAGE POINT

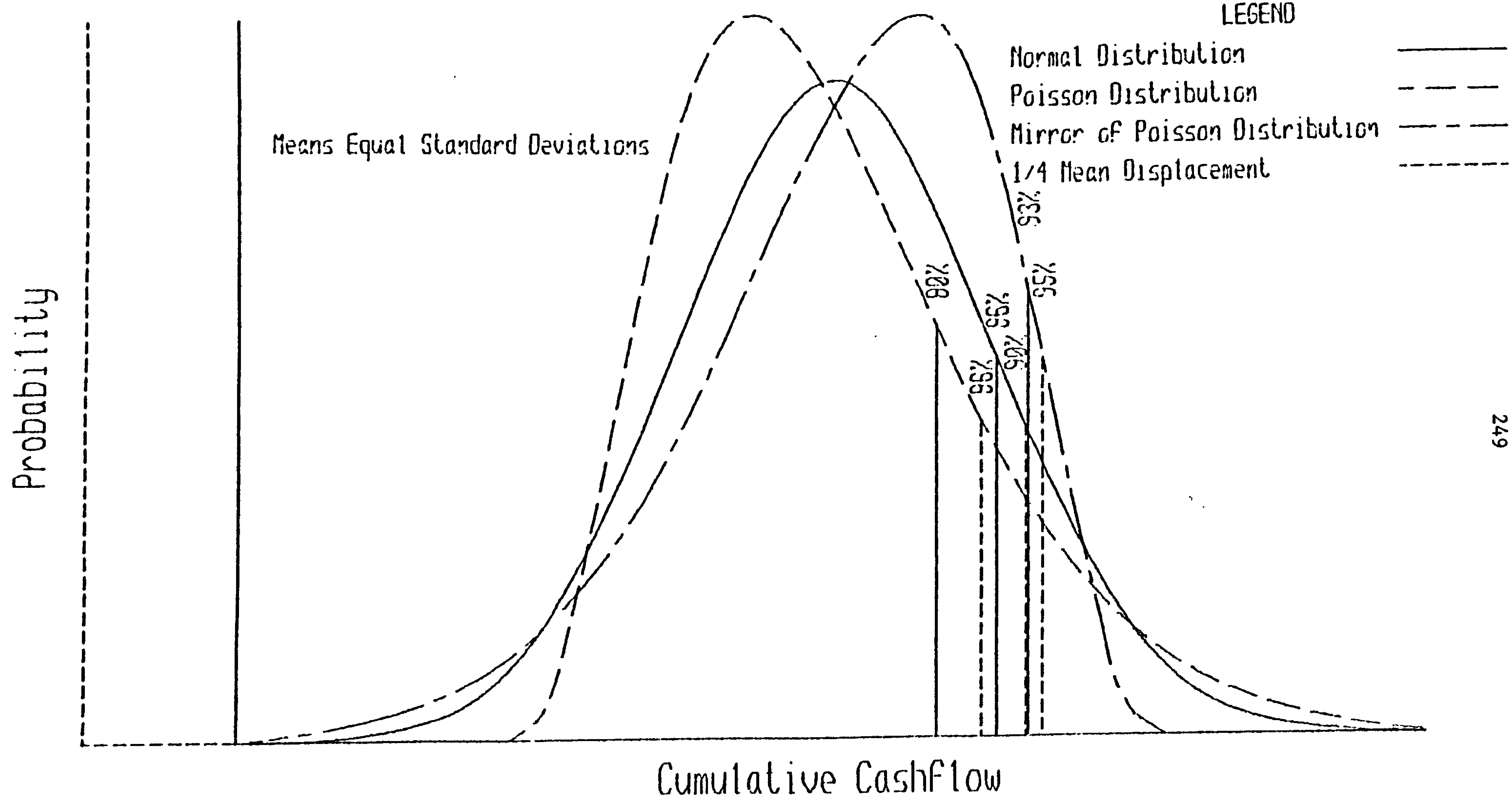


FIGURE 6-23
OPTIMUM COVERAGE ANALYSIS

slope). Therefore, the change in investment required for optimum coverage by the Poisson distribution is greater than the change in investment required for optimum coverage by the normal distribution which is greater than the change in investment required for optimum coverage by the Mirror-of-Poisson distribution.

6.3.3.1.1 Imperfect Capital Markets

In the perfect capital market transaction costs can be ignored.[78] This assumption was made in this study with regard to optimum coverage:

$$P'(I) = \frac{1}{I}$$

But in the imperfect capital market an investment firm charges a fraction of the stock purchase price for conducting the transaction. Where a new issue is involved, with the investment firm's reputation more vulnerable than in everyday trading of common stock, the cost can be significant (20-40%) and the optimum coverage point becomes:

$$P'(I) = \frac{1 - X}{I}$$

where

X is the fraction of the sales price kept as a sales commission.

6.3.3.1.2 Optimum Coverage Summary

Optimum coverage provides a method of determining the optimum cash to have available before commencing a project--given the period-by-period cash requirements as probability distributions. It is not unusual for otherwise profitable operations to experience an unanticipated cashflow crisis and wind up in bankruptcy. Optimum coverage, for those willing to build the models, will provide the appropriate level of insurance.

This analysis considers a project that has only one major cashflow minimum. The procedure should be even more advantageous for large firms starting several projects at several different times and, hence, several cashflow minimums. The procedure allows the critical time period and value to be found as a function of the probabilistic variables involved.

If the firm finds a cashflow problem sufficiently far in the future it has the option of retaining its earnings, arranging for extra debt or equity financing before the problem occurs, or abandoning the problem project(s).

6.3.3.2 Optimum Net-Present-Value

The second method of determining the cash required is the optimum net-present-value method. It is computed by beginning with the best cumulative-cashflow scenario and discounting the difference between successive periods, the cashflow during the period, by the appropriate discount rate. If the sum of the discounted values is greater than zero, the same procedure is followed for the next best cumulative-cashflow scenario and so on, continuing until the last scenario with a net-present-value equal to or greater than zero is found. The minimum cumulative-cashflow point of this last cumulative-cashflow scenario is the amount of capital an investor would want to invest, with no opportunity for reinvestment at a future time, to optimize his net-present-value.

Because, in this instance, interest expense has already been deducted from the cumulative cashflows, any discounting will result in a return-on-equity, not a return on the average-weighted cost of capital. Thirteen percent is used as the discount rate. In this analysis, the procedure was performed on cumulative cashflows that had been ordered period-by-period; this is explained in Section 6.3.4.

6.3.3.3 Optimum Net-Present-Value Per Invested-Dollar

The third method of determining the cashflow required is the optimum net-present-value per invested-dollar method. The optimum net-present-value per invested-dollar is found by starting with the best cumulative-cashflow scenario and discounting it as above (Section 6.3.3.2) and with the same caveats. Next, the minimum cumulative-cashflow point of the scenario is discounted period-by-period at the risk-free rate (4%, the return on 30-day treasury bills) and its absolute value taken. This value is then divided into the optimum net-present-value. After incrementing to the next cumulative-cashflow scenario the second discounted absolute minimum value is divided into the sum of the first and the second discounted cumulative-cashflow scenarios and so on, until the resultant quantity first decreases. The last point of increase is the cumulative-cashflow scenario that gives the optimum net-present-value per invested-dollar. The minimum cumulative-cashflow point of this last cumulative-cashflow scenario is the amount of capital an investor would want to invest, with no opportunity for reinvestment at a future time, to optimize his net-present-value per invested-dollar. It is always less than the optimum net-present-value investment.

6.3.4 Cumulative-Cashflow Graphs

In order to analyze the cumulative-cashflow distributions, it was necessary to order the cumulative cashflows from 1 to 1002, by value, within each time period (six time periods per year). It is important that the cumulative cashflows are first generated and then ordered if there are events in the simulation which can occur at different times; otherwise, the effect of the timings will be destroyed and misleading answers will be produced.

The ordering of the cumulative cashflows is done by a sort routine. A graphical representation of the process is given in Figure 6-24. The 501st (median) simulation is discarded leaving 1001 simulations and exactly 200 simulations between each percent-chance-of-exceeding line if the percent-chance-of-exceeding lines are at 20% intervals. The resulting cumulative cashflows are good representations of the model even though any specific cumulative-cashflow line may not represent any specific simulation.

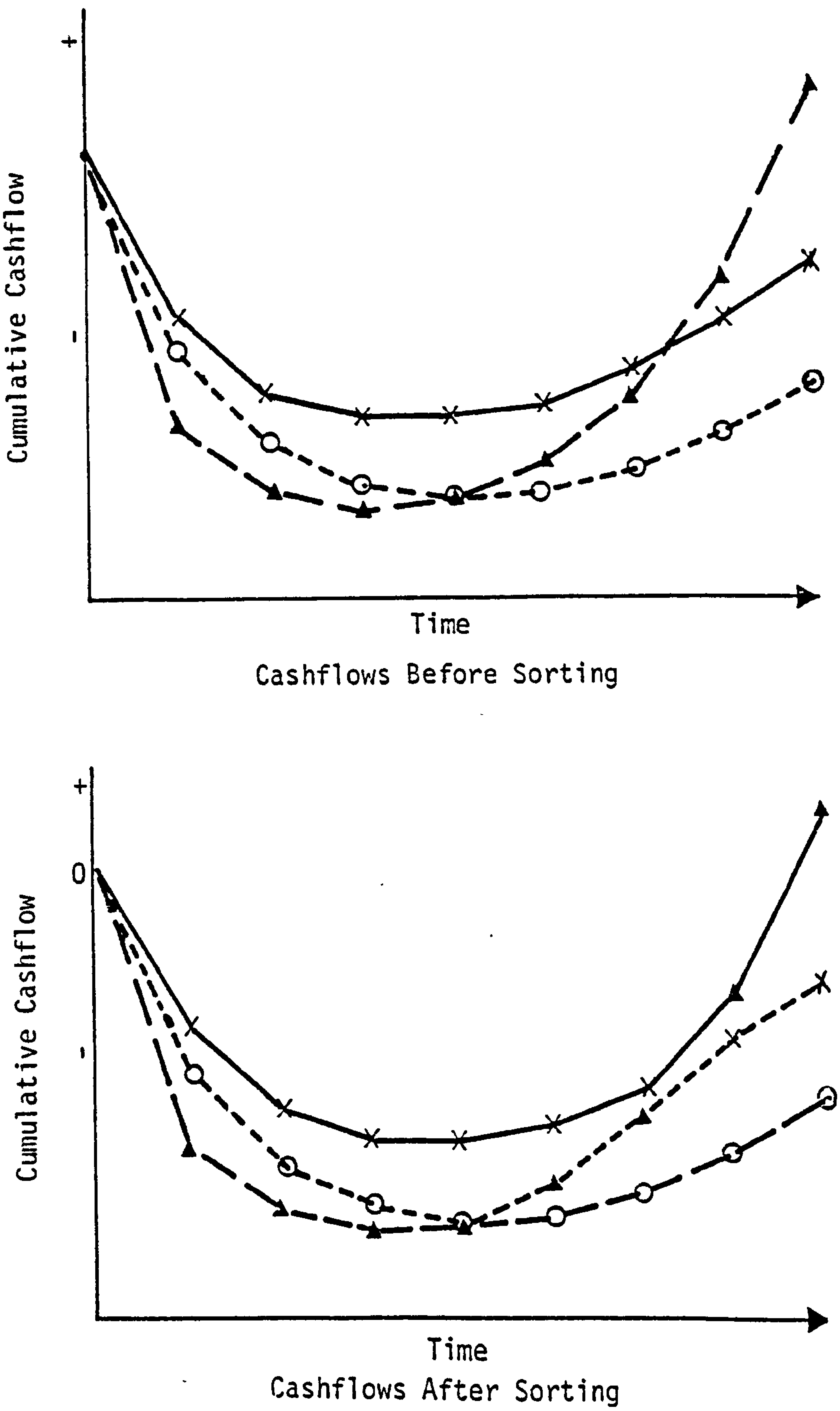


FIGURE 6-24
EFFECT OF CUMULATIVE CASHFLOW SORTING

If there is something inherent in the model that says a small initial investment requirement preordains a small positive cashflow in the future (a small operation) and that a large initial investment requirement preordains a large positive cashflow in the future, then the ordered cumulative-cashflow graphs become suspect. The process of optimum coverage still works--it is the representation of any particular simulation by a cumulative-cashflow line that is in doubt.

After the cumulative cashflows were sorted for all sixty time periods, the optimum coverage point was found period-by-period and the minimum optimum coverage point selected. This minimum point occurs sometime after the airline is initiated. The investment required was discounted back along the optimum coverage line to initiation to find the investment required at initiation. The money was assumed to be invested in 30-day treasury bills at 4% interest. Therefore, if cash flowed out as represented by the optimum coverage line, the initial investment plus the interest would provide enough funds to reach the optimum coverage point. (The same procedure was followed for the minimum cash required points for the optimum net-present-value and optimum net-present-value per invested-dollar methods.)

Once the zero percent-chance-of-exceeding cumulative-cashflow line reaches payback the reference point for optimum cashflow is transferred from the zero cumulative-cashflow line to the 0% chance-of-exceeding line. (It is important that this transference take place after the optimum coverage point has been computed. The optimum coverage point must be referenced to zero or it isn't valid.) What begins at this point is an optimum coverage line which gives an idea of the safe dividends that may be paid to stockholders, while optimally protecting the remaining probable cashflows. The difference between actual cashflows, which exceed the optimum coverage line, and the optimum coverage line is retained earnings. Looking at the optimum coverage line in the future, the cumulative dividends at any time should not exceed the difference between the current or any future lesser value of the optimum coverage line and the zero cumulative-cashflow line. However, this decision, from a practical standpoint, must take into account the return-on-equity, retained earnings, and the other investment opportunities available. As the project progresses, new cumulative cashflows based on the latest data should be projected. It is on these latest forecasts that the optimum coverage line and subsequent dividends to stockholders should be based.

The percent-chance-of-exceeding cumulative-cashflow lines for an airline purchasing aircraft (debt financing) are shown in Figure 6-25. The annual fluctuations of the graphs are the result of the seasonal traffic fluctuations. The solid line extending out from zero and transferring to the top of the zero percent-chance-of-exceeding line is the reference line for optimum coverage. The optimum coverage, optimum net-present-value, and optimum net-present-value per invested-dollar lines are all between the 80% and 100% chance-of-exceeding lines throughout the ten-year period. For a thirteen percent return-on-equity, the optimum coverage line is generally above the other two lines. This indicates that in a perfect capital market with wholly logical investors, requiring 13% on equity, optimum coverage financing should be readily available. There is a relative rise in the optimum coverage line at two points: where the reference line transitions from the zero cumulative-cashflow line to the 0%

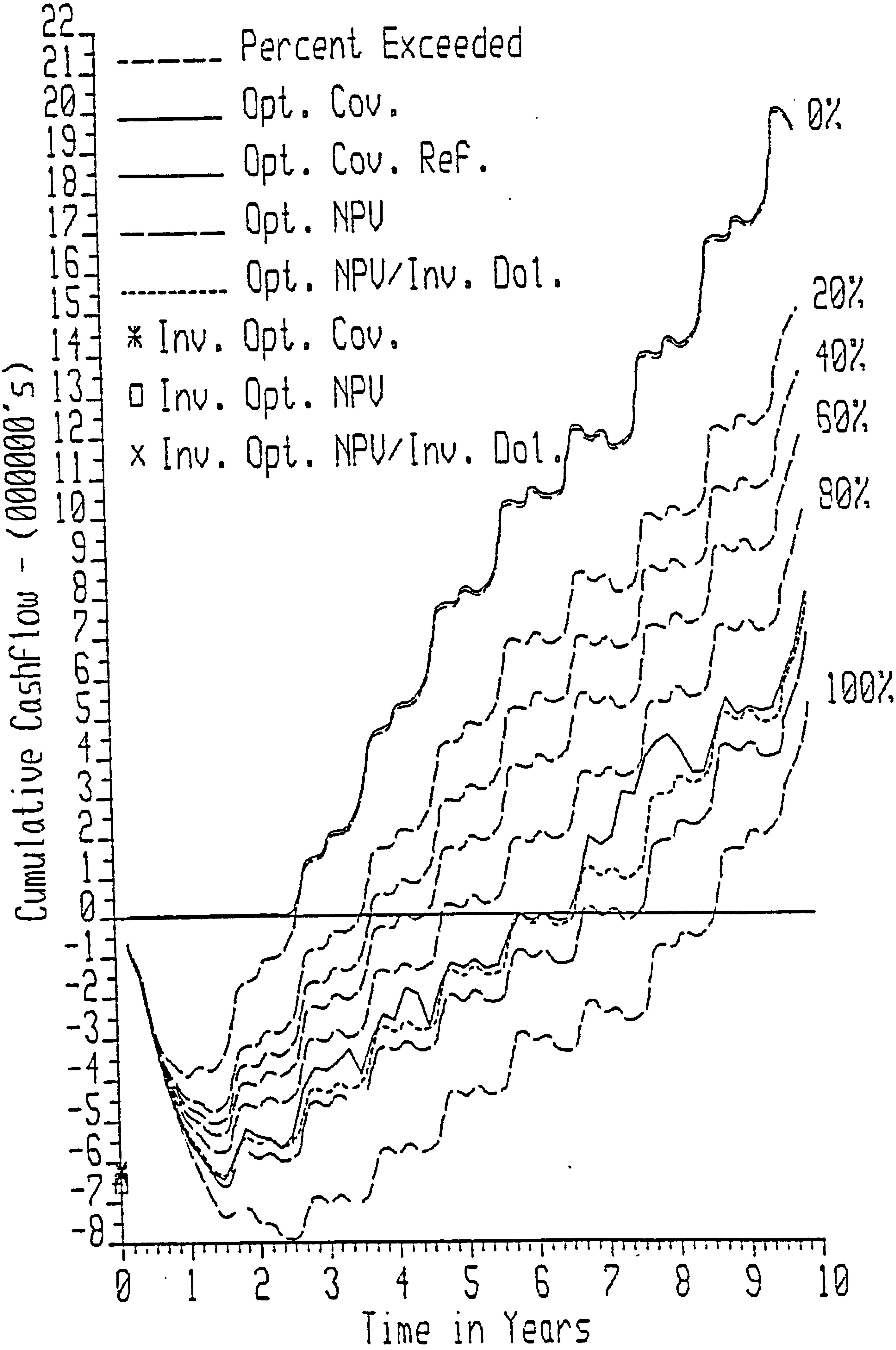


FIGURE 6-25
CUMULATIVE CASHFLOWS FOR AIRCRAFT PURCHASED

chance-of-exceeding line, and in the seventh year when the aircraft are being paid-off. In the eighth year, it moves back near its previous relative position. Optimum coverage is a period-by-period analysis--the value in one period does not affect the value in others.

The increase in positive cashflows after the aircraft are paid-off in year seven is most pronounced in the 100% chance-of-exceeding line where relief is needed most. The rise of the cashflows at the end of year ten is caused by the sale of aircraft. The slight downturn of the 0% chance-of-exceeding line in yeat ten is caused by taxes due.

The times at which the percent-chance-of-exceeding-cumulative-cashflow lines cross the zero cumulative-cashflow line form the probability distribution of the undiscounted payback period.

On the ordinate an asterisk, box, and cross indicate the minimum points of optimum coverage, optimum NPV, and optimum NPV per invested-dollar, respectively, and which have been discounted at 4% along their respective lines back to airline initiation.

The airline as a tax shelter is shown in Figure 6-26. This graph is identical to the aircraft purchased graph (Figure 6-25) for the first 32 months; the only difference being the location of the optimum NPV and optimum NPV per invested-dollar lines, which are now above the optimum coverage line and are often less than the 80% chance-of-exceeding cumulative-cashflow line. The optimum net-present-value and optimum net-present-value per invested-dollar lines are a function of cashflows in all time periods so they are affected in the early periods by later periods. The only difference between the airline as a tax shelter and the airline purchasing aircraft is that the airline as a tax shelter lacks the tax benefits which were carried forward before. It still has the use of the depreciation that would normally occur in each of the profitable periods, but the loss of the early depreciation and investment tax credit affects later cashflows. The lack of tax benefits is most pronounced in years three through five for the 0% chance-of-exceeding line and years five through nine for the 100% chance-of-exceeding line, indicating when the airline would normally be using the tax benefits. This contributes to the lack of compactness (cumulative-cashflow difference between 0% chance-of-exceeding line and 100% chance-of-exceeding line) of the tax shelter solution when compared to the others. The rest of the properties of the tax shelter graph are similar to the aircraft purchased graph.

There are considerable tax benefits available for a parent firm. Table 6-9 gives the available tax benefits and the standard deviation of tax benefits if the airline is used as a tax shelter; the benefits are undiscounted and before tax. The decrease in the mean and the relative increase in the standard deviation in years 1980 and 1981 is caused by the airline, in some of the scenarios, competing for the benefits.

The scenarios where aircraft are leased with the airline retaining the investment tax credit are shown in Figure 6-27. The cashflows in this case do not dip as low as in the previous two cases. Most pronounced is the improvement in the 100% chance-of-exceeding line which recovers much quicker than in the aircraft purchased or tax shelter case. The solution is generally more compact (cumulative-cashflow difference

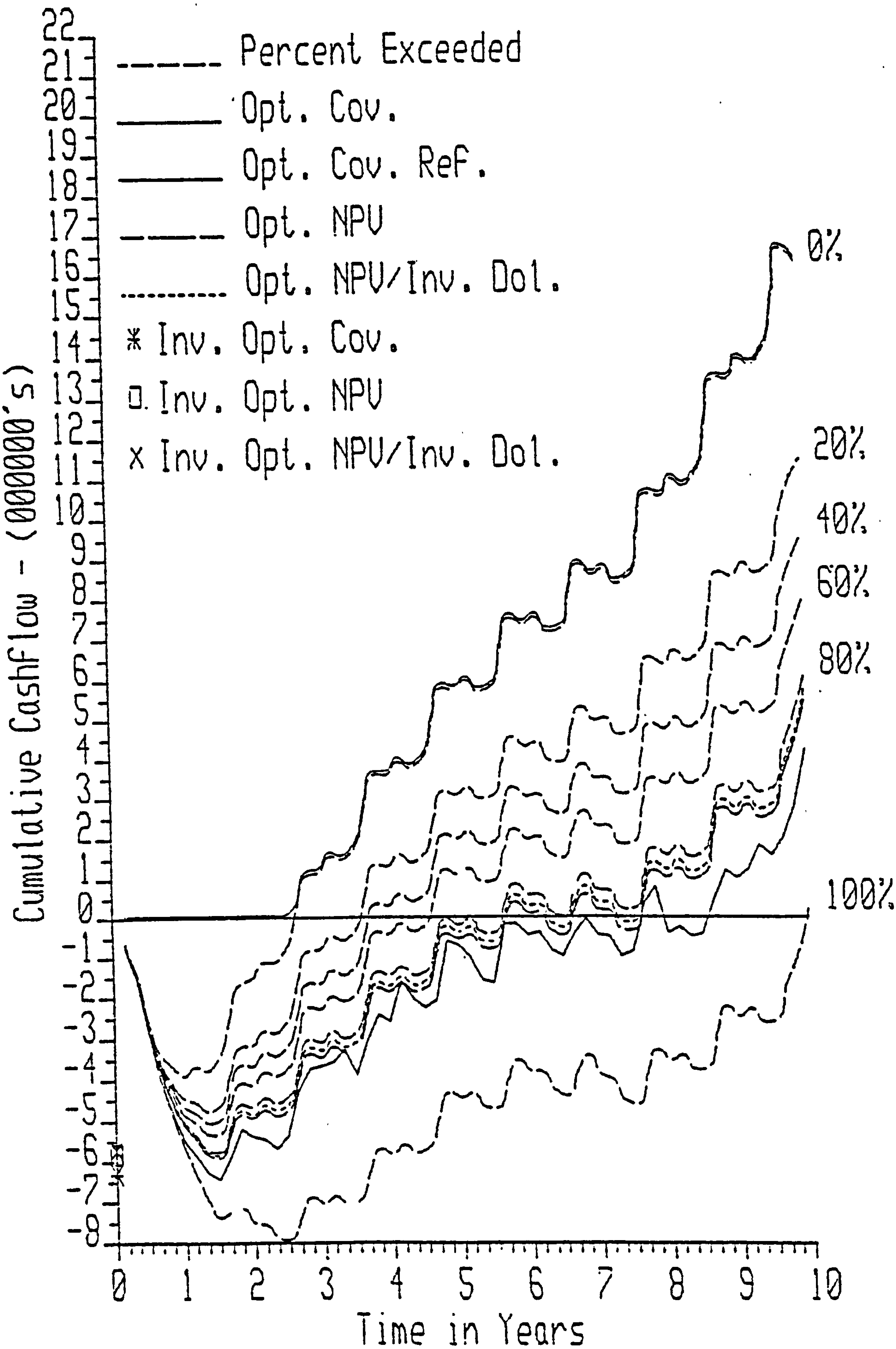


FIGURE 6-26
CUMULATIVE CASHFLOWS FOR THE AIRLINE AS A TAX SHELTER

TABLE 6-9

TAX BENEFITS AVAILABLE IF THE AIRLINE IS USED AS A TAX SHELTER

	Depreciation ($)		Investment Tax Credit ($)	
Year	μ	σ	μ	σ
1978	3699487	330821	1039195	28306
1979	1194583	673742	127656	71865
1980	151427	269205	5585	4120
1981	8604	51149	327	520

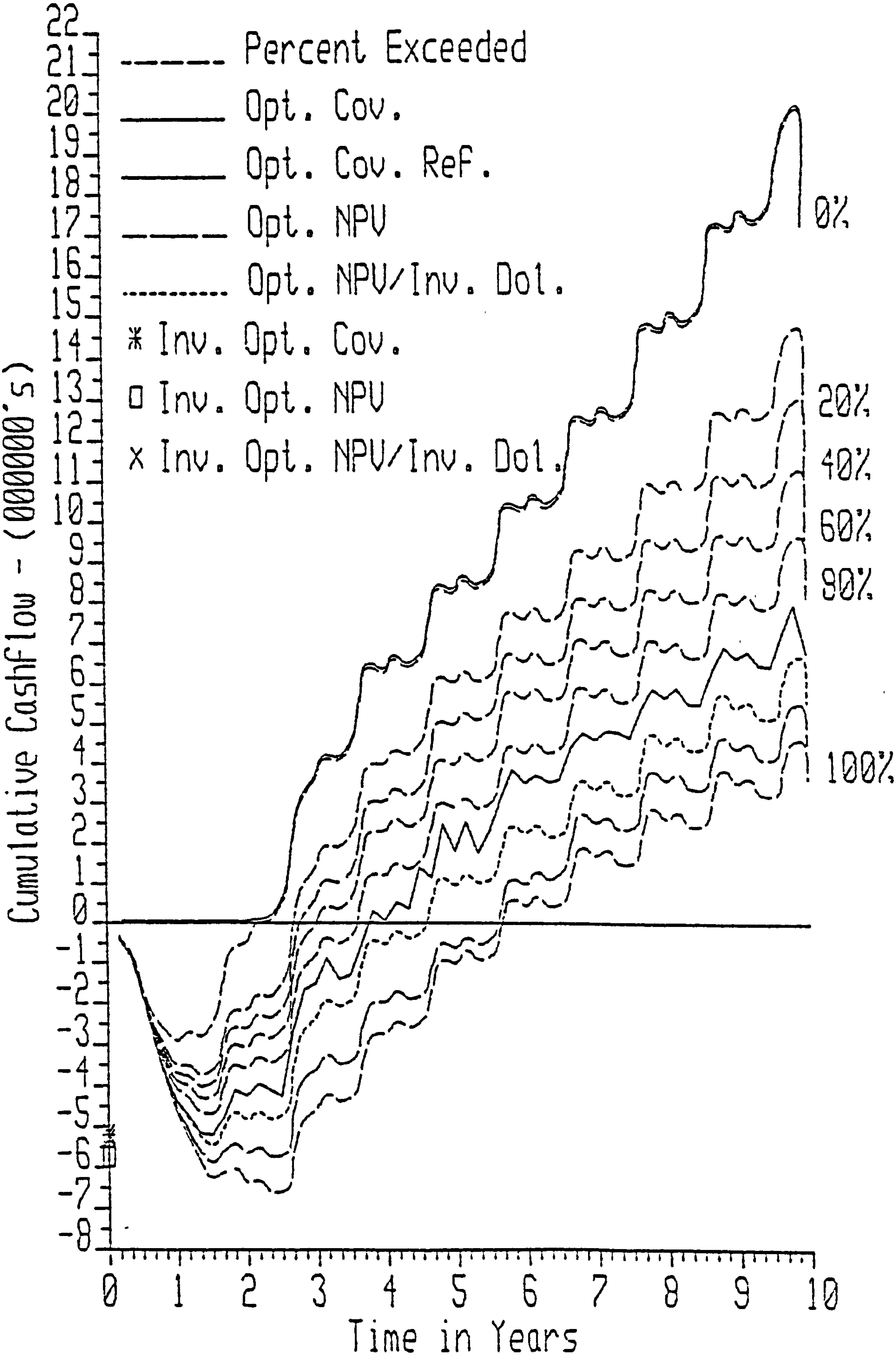


FIGURE 6-27
CUMULATIVE CASHFLOWS FOR AIRCRAFT LEASED WITH INVESTMENT TAX CREDITS

between the 0% chance-of-exceeding line and the 100% chance-of-exceeding line) than the previous solutions. The optimum coverage line is well above both the optimum NPV and the optimum NPV per invested-dollar lines.

The repayment of the 10% deposit (plus 4.5% interest) after 30 months is clearly visible; 11.16% of the retail price of the aircraft is repayed.

The downturn in the last period is due to taxes and lease payoffs. In both lease cases, the aircraft are not sold by the airline at the end of the ten-year period, but returned to the lessor.

The scenarios where the aircraft are leased and the airline forfeits the investment tax credit are shown in Figure 6-28. In this case, the optimum coverage line is well above both the optimum NPV line and the optimum NPV per invested-dollar line. Indeed, the optimum NPV line is coincident with the 100% chance-of-exceeding line. This solution has the smallest cash requirement to start.

6.3.4.1 Summary of the Cumulative-Cashflow Graphs

Table 6-10 summarizes the cash required for the various methods of finance, and the percent of time it will be sufficient for the various appraisal methods. With the straight aircraft purchase and tax shelter, 6.447 million dollars is required to start up by the optimum coverage solution. With the aircraft leased and the ITC retained by the airline, 5.207 million dollars is required, and, with the ITC returned to the lessor, 4.624 million dollars is required, to start up by the optimum coverage method. The table also gives the time to the optimum coverage point--eighteen months for all scenarios except for the aircraft leased with the ITC retained by lessor when it is sixteen months.

6.3.4.2 Range of the Cumulative Cashflows

The range ($4.6 million) of the cumulative cashflows for aircraft purchase or tax shelter at eighteen months is attributed to passengers or revenue ($2.8 million), aircraft ($1.0 million), inflation and prime rate ($0.4 million), and all others, e.g., spares, office and hangar, ($0.4 million). (The variation caused by the aircraft is even less in the two lease cases.) This re-emphasizes the importance of proper traffic estimation to airline success.

6.3.4.3 Pseudo-Returns on Equity

Because there is nothing in the model which requires a low (high) investment preordain a low (high) return-on-investment, the percent-chance-of-exceeding cashflow lines may be considered to be pseudo-cashflows. These may then be checked for pseudo-returns-on-equity. The return is on equity because the cost of interest has already been deducted. The pseudo-return-on-equity is simply:

$$\sum_{t=1}^{60} \frac{CF_t}{(1 + PRE/100)^{t/6}} = 0$$

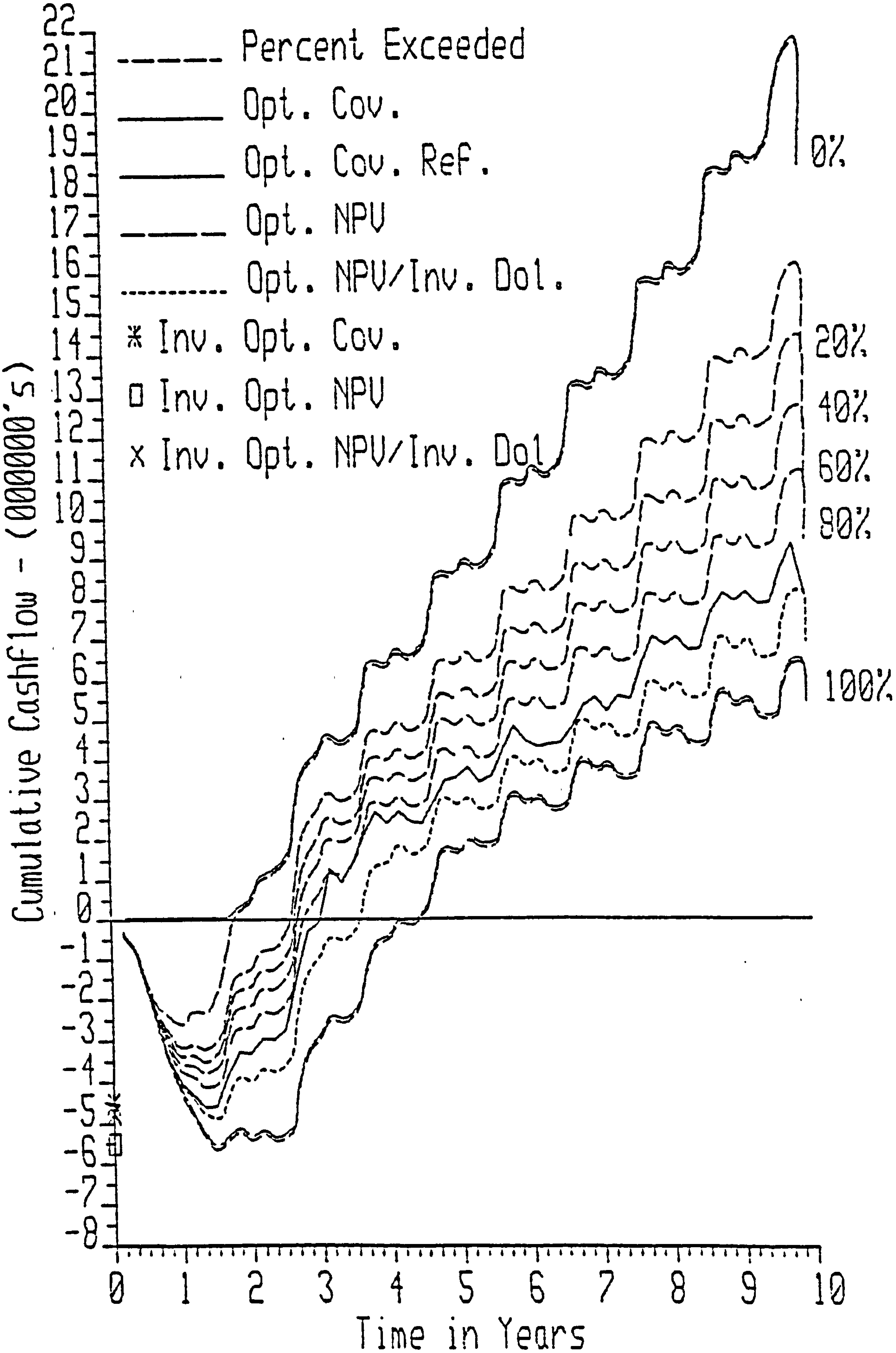


FIGURE 6-28
CUMULATIVE CASHFLOWS FOR AIRCRAFT LEASED WITHOUT INVESTMENT TAX CREDITS

TABLE 6-10

METHOD OF DETERMINING CASH REQUIRED
vs
METHOD OF FINANCE

METHOD OF DETERMINING CASH REQUIRED	METHOD OF FINANCE: Straight Aircraft Purchase	Airline As Tax Shelter	Aircraft Leased ITC Retained By Airline	Aircraft Leased ITC Retained By Lessor
OPTIMUM COVERAGE				
% of Time Covered	96.1	96.1	94.4	95.1
Investment (000000s)				
Required	6.447	6.447	5.207	4.624
Discounted @ 4%	6.317	6.317	5.093	4.527
to Start Up Inflow = Outflow	18 mos.	18 mos.	18 mos.	16 mos.
OPTIMUM NPV				
% of Time Covered	97.2	85.6	99.4	100.0
Investment (000000s)				
Required	6.638	5.922	5.873	5.644
Discounted @ 4%	6.498	5.808	5.731	5.507
OPTIMUM NPV/INVESTED DOLLAR				
% of Time Covered	94.9	83.5	97.0	97.5
Investment (000000s)				
Required	6.360	5.857	5.445	4.880
Discounted @ 4%	6.230	5.745	5.318	4.772

where

> t is the time period (six per year),
>
> CF_t is the cashflow in time period t, and
>
> PRE is the pseudo-return-on-equity in percent that makes the equation zero.

The results of this discounting are given in Table 6-11. Returns-on-equity are of more importance to the stockholder than the business manager who is more interested in satisfying the firm's return-on-investment or average-weighted cost of capital. The table shows that the airline reaches payback in every instance, and that the pseudo-return-on-equity may reach 105%--lease with the investment tax credit being retained by the lessor.

6.3.4.4 The Time to Start Up

As stated in Section 6.3.2.5, it was not possible to use the PROSPER program to find the optimum time to start up. This was done by another computer program that used the same probability distributions and the same seasonal traffic fluctuations as PROSPER.

The fraction of mature 1978 traffic generated at eighteen months is given in Table 6-12. The airline was started by PROSPER in December-January, this means that flights and revenue started in April-May. This timing corresponds to 0.73223 of mature demand in 1978. By starting the airline in June-July and flights in October-November the fraction at eighteen months becomes 0.76586. An October-November start up of flights is equivalent to $334240 less cash required--5.3% of the cash required for aircraft purchased or the airline as a tax shelter, 6.6% of the cash required for lease with ITC retained by the airline, and 7.4% of the cash required with ITC retained by lessor. This is contradictory to the actions of third-level operators who try to start their first scheduled flights in the spring; however, they would not necessarily need to consider the rate of aircraft acquisition.

6.3.5 Selection of Aircraft Financing

The remaining decision is which financing alternative should be pursued, i.e., aircraft purchased (debt financing), airline as a tax shelter, lease with investment tax credit retained by the airline, and lease with investment tax credit retained by the lessor.

The same airline simulations used to develop the cumulative cashflows were used to develop the probability density functions and the cumulative probability distributions for net-present-value and internal-rate-of-return for each of the four financing alternatives.

6.3.5.1 Net-Present-Value and Internal-Rate-of-Return

The net-present-value of the airline is determined by PROSPER from the equation:

TABLE 6-11

PSEUDO-RETURNS ON EQUITY (%)

Probability of Exceeding Cashflow Line	Aircraft Purchased	Airline As Tax Shelter	Aircraft Leased With ITC	Aircraft Leased Without ITC
0%	63	54	89	105
20%	41	34	57	70
40%	34	27	49	60
60%	29	22	41	52
80%	23	16	33	44
100%	8	0	11	20

TABLE 6-12

CUMULATIVE TRAFFIC (REVENUE) AFTER 12 MONTHS OF FLIGHT OPERATIONS VERSUS THE PERIOD OF FIRST FLIGHT
(18 Months After Airline Incorporation)

First Flight Operation	Cumulative Traffic (Revenue) of a Mature First Year
December-January	0.74555
February-March	0.75970
April-May	0.73223
June-July	0.70206
August-September	0.72791
October-November	0.76586

$$NPV = \sum_{t=1}^{60} \frac{CF_t}{(1 + i/100)^{t/6}}$$

where

NPV is the net-present-value,

t is the time period (six periods per year),

CF_t is the cashflow plus interest expense in period t, and

i is the discount rate or the average-weighted cost of capital, 13%, as determined in Section 1.5.3.1.

If the discount rate, i, is set to zero and the equation solved then the net-present-value is simply the sum of the cashflows. As the discount rate approaches infinity the net-present-value approaches asymptotically the first cash outflow. If the net-present-value is set equal to zero and the discount rate (i) is solved for, then the solution is the internal-rate-of-return:

$$\sum_{t=1}^{60} \frac{CF_t}{(1 + i/100)^{t/6}} = 0.$$

6.3.5.2 Net-Present-Value Graphs

The decision to purchase the aircraft is shown in Figure 6-29. The discount rates, both earnrate and payrate, are 13%. The net-present-values along the ordinate, and the mean value (4223.15) and the standard deviation (1919.24) at the top of the page, are in thousands of dollars. The mean of the distribution, $4.2 million dollars, is significant in terms of the size of the investment and the discount rate. There is a 1.2% chance of a negative net-present-value (based on the average-weighted cost of capital) and a 2.8% chance of solutions below the optimum NPV (Table 6-10) which is based on the cost of equity (also taken as 13%).

The probability density function was checked by the Kolmogrov-Smirnov test and was not normally distributed. This is contrary to what Hull[23] suggests. A possible explanation is that an insufficient number of simulations were done; this does not seem likely. Inspecting the frequencies along the ordinate suggests that more than one peak may be present. If this is the case, then the demand disaggregation into five equal pentiles was insufficient. The problem is more likely insufficient demand disaggregation than insufficient cost disaggregation because the demand pentiles are both equally likely (20% probability) and more influential (Table 6-5).

The airline as a tax shelter is shown in Figure 6-30. The comments applicable to the aircraft purchase graph are applicable to this graph and subsequent graphs as well--specific values excepted. This graph shows the airline stripped of its tax benefits in the year they become available, if it cannot use them in that year. It is the worst

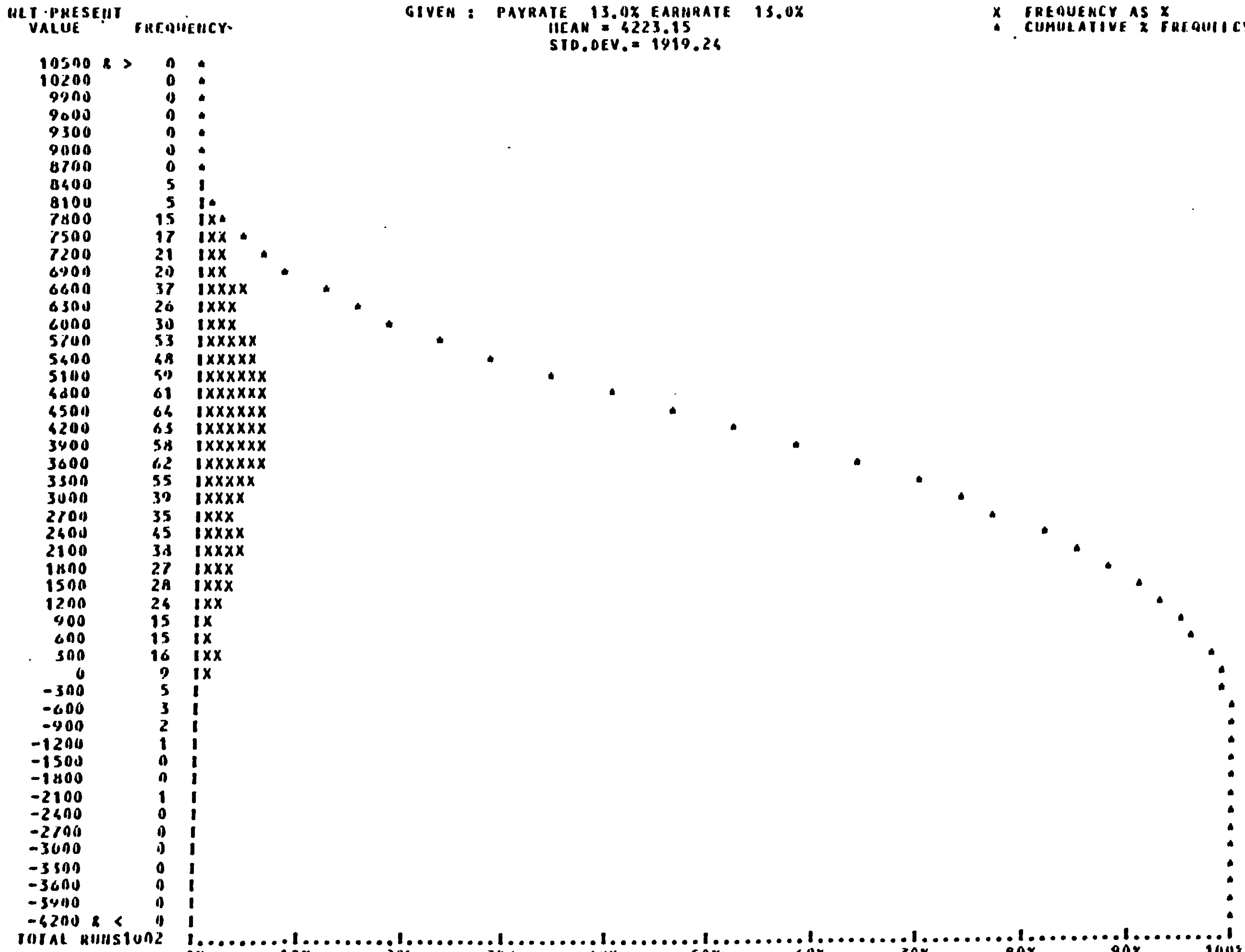


FIGURE 6-29
NET-PRESENT-VALUE FOR AIRCRAFT PURCHASED

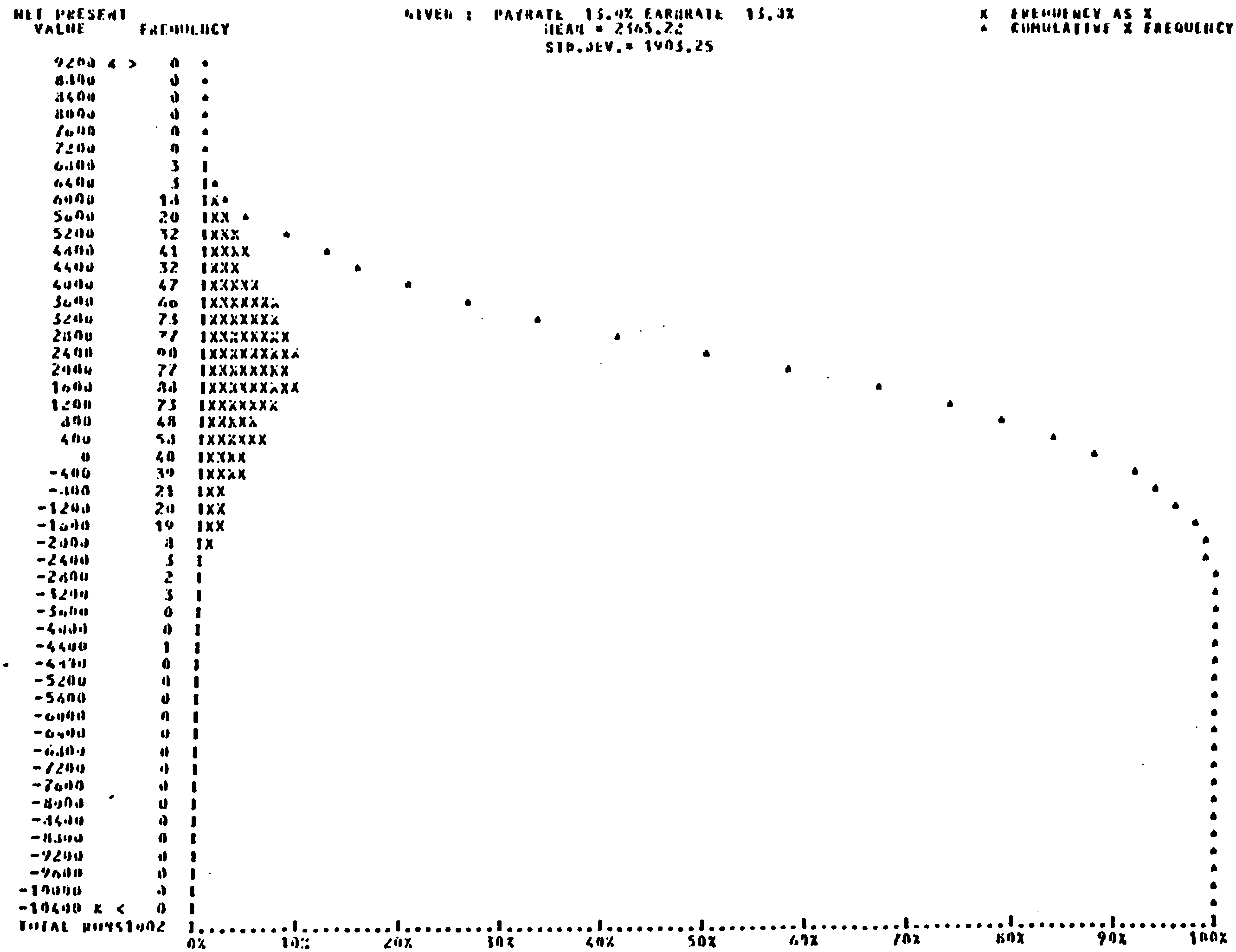


FIGURE 6-30
NET-PRESENT-VALUE FOR THE AIRLINE AS A TAX SHELTER

solution when viewed by itself. When the NPV of the tax benefits are used immediately by a parent firm, it becomes the best solution. This is discussed later. The airline has an 11.6% chance of a negative net-present-value and 14.4% chance of solutions below the optimum NPV (Table 6-10). The mean net-present-value for the airline by itself is $2.4 million--still a good investment.

With the aircraft leased and the investment tax credit retained by the airline, not only does the NPV increase, but the standard deviation decreases as well (Figure 6-31). There is only a 0.1% chance of a negative net-present-value (one solution) and a 0.6% chance of solutions below the optimum NPV (Table 6-10).

The best solution, not requiring the financial backing of another firm, is with the aircraft leased and the investment tax credit retained by the lessor. This solution is given in Figure 6-32. The mean net-present-value is $5.6 million and the standard deviation is only $1.5 million. The net-present-value is never negative and the optimum NPV corresponds to the 100% chance-of-exceeding line.

6.3.5.3 Net-Present-Value Versus Discount Rate

The net-present-value for a 0% discount rate and the internal-rate-of-return for each of the four methods of finance were determined. The net-present-value at 0% and 13% discount rates and the internal-rate-of-return for the airline as a tax shelter with the tax benefits of the parent firm included was also determined. The results are shown in Figure 6-33, and are exactly what would be expected. The proper financing decision is a function of the discount rate. The higher the discount rate the more important it becomes that tax benefits be used early. Therefore, the leases outperform a straight aircraft purchase at all but the lowest discount rates. The straight aircraft purchase is better than a lease without the ITC (ITC retained by lessor) up to a 2% discount rate, and better than a lease with the ITC retained by the airline up to an 8.5% discount rate. Lease without the ITC (ITC retained by lessor) outperforms lease with the ITC (ITC retained by airline) at all discount rates and does so by a greater margin at higher discount rates. The airline as a tax shelter--excluding tax benefits that would need to be carried forward--gets to use very few of the tax benefits; hence, this is the worst solution. The tax shelter becomes the best solution when the tax benefits to the parent company are included because all the tax benefits are in-house and immediate. The airline must "pay" the lessor for the lessor's ability to use the tax benefits immediately in a lease.

The difference between the tax shelter and the straight aircraft purchase at zero discount rate is due to the seven-year limit that investment tax credits may be carried forward, and to the amount of tax in excess of $25000 that may be reduced by ITC in the years after 1979 (Table 6-8).

A summary of the data from which Figure 6-33 was prepared is given in Table 6-13. Note that the standard deviation always decreases with an increase in the discount rate because its value is being discounted at a higher discount rate.

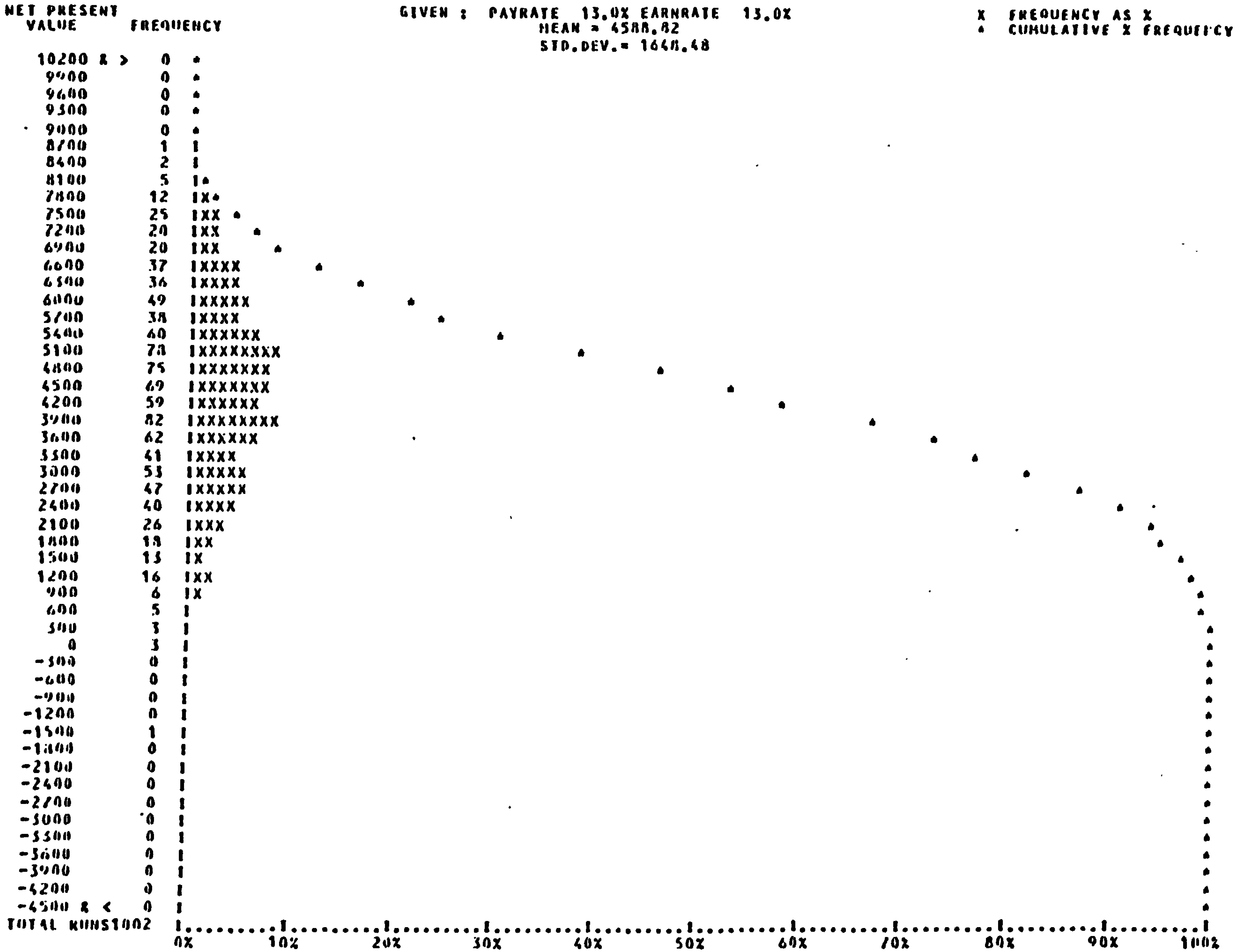


FIGURE 6-31
NET-PRESENT-VALUE FOR AIRCRAFT LEASED WITH INVESTMENT TAX CREDIT RETAINED

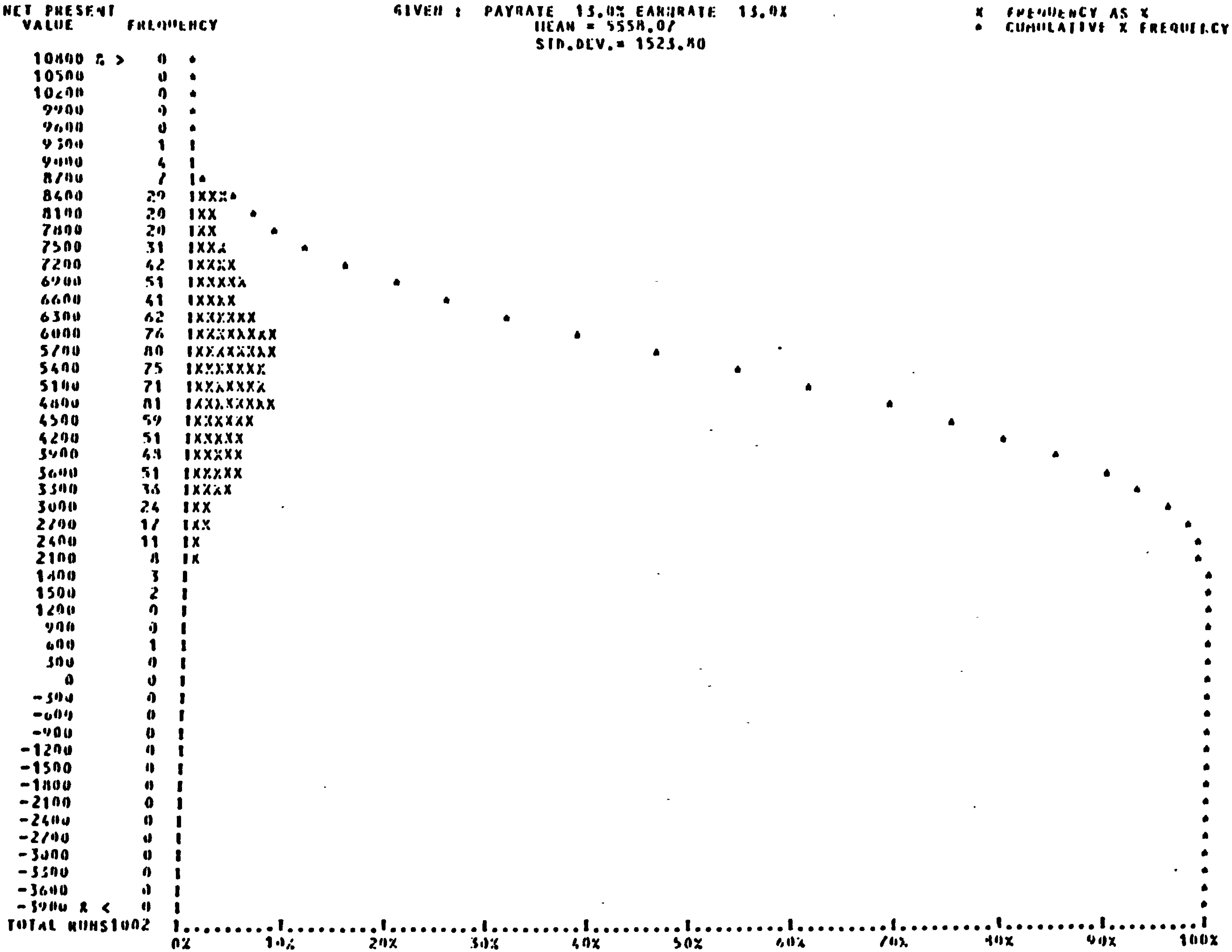


FIGURE 6-32
NET-PRESENT-VALUE FOR AIRCRAFT LEASED WITHOUT INVESTMENT TAX CREDITS

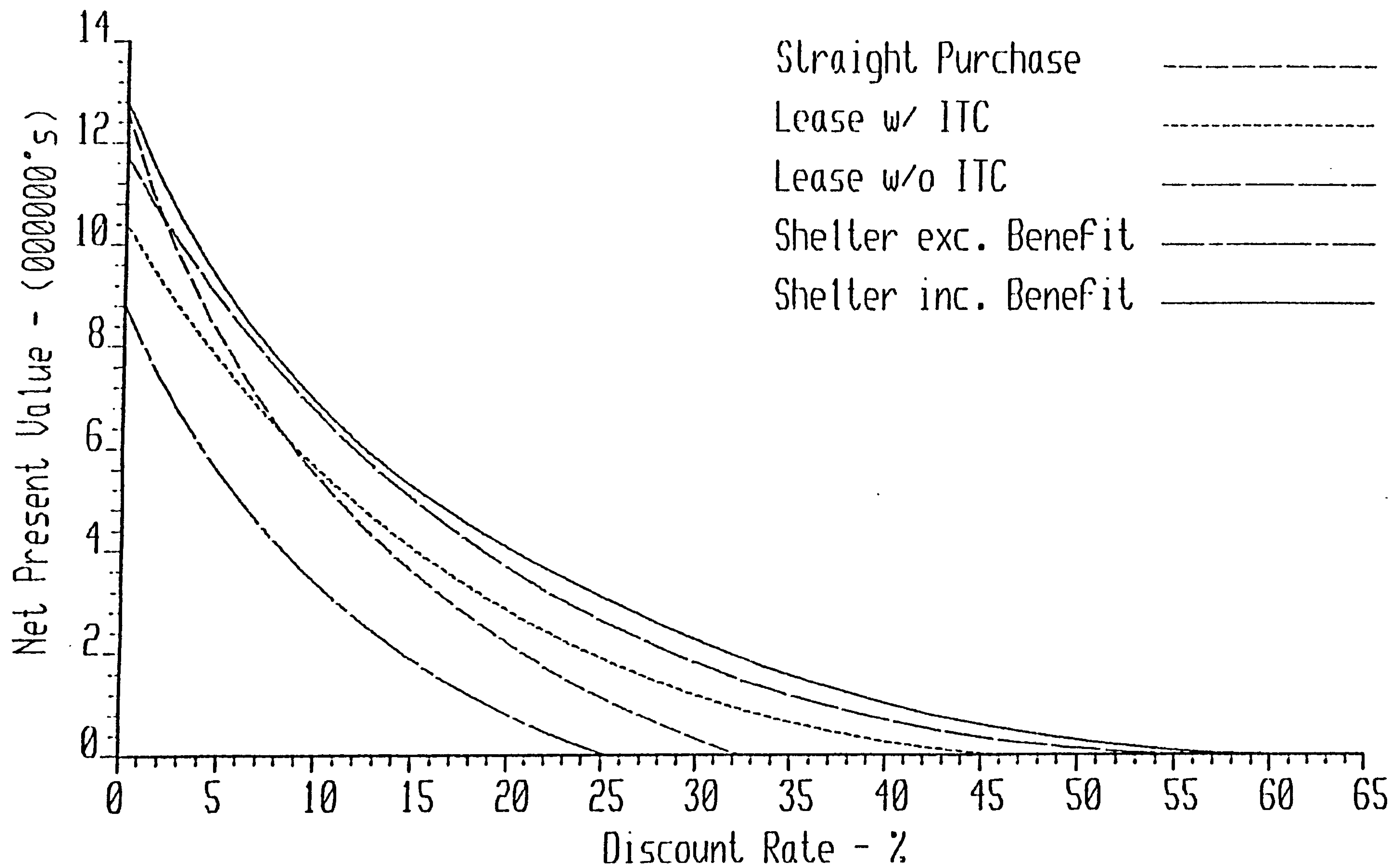


FIGURE 6-33
NET-PRESENT-VALUE VERSUS DISCOUNT RATE

TABLE 6-13

FINANCE METHOD VS NPV AT VARIOUS DISCOUNT RATES

FINANCE METHOD	DISCOUNT RATE (%) 0%		13%		IRR[2]	
	μ-NPV[1]	σ-NPV[1]	μ-NPV[1]	σ-NPV[1]	μ-%	σ-%
Aircraft Purchased	12.6	2.8	4.2	1.9	32.3	9.9
Tax Shelter exc. Benefits	8.8	3.1	2.4	1.9	25.2	9.9
Tax Shelter inc. Benefits	12.8	3.2	5.8	2.0	62.2	13.0
Aircraft Leased w/ITC Retained	10.4	2.6	4.6	1.6	45.6	13.3
Aircraft Leased w/o ITC	11.7	2.5	5.6	1.5	57.5	14.0

1 NPV in millions of dollars
2 IRR is the Internal Rate of Return (IRR) or Return on Investment (ROI)

The mean value of the internal-rate-of-return makes any selection an excellent investment when compared to the Forture top 10 (2% of the Fortune 500 companies); these companies have a return-on-investment of 25% or more.

6.3.5.4 Financial Summary

The airline should be operated as a tax shelter so that all the tax benefits can be used immediately by the airline or the parent company. If this is not possible, and the airline has a average-weighted cost of capital exceeding 2%, it is best to sell as many tax credits as possible in order to acheive the best possible financial lease.

If the financial terms offered are different from those assumed, another simulation is probably in order; pending an investigation of the differences in the financial terms.

RESULTS AND CONCLUSIONS

GENERAL

The results of the analysis must be viewed in the proper context. The thesis develops a methodology for appraising whether or not a third-level airline should be undertaken, using a hypothetical airline in Oregon as an example. The overall financial results indicate that such a venture in Oregon should be profitable. The methodology does not account for the actions of an aggressive, responsive management to general (inflation, etc.) or specific (airline related) economic changes in the management's attempt, on a virtually day-to-day basis, to maximize the short-term contribution and, hence, the long-term return-on-investment of the airline.

For example, no airline would be content with an annual growth rate of 1-2% in its markets when the markets of other carriers are growing more quickly (neither would their markets). The growth could be spurred by differential fares (once a market is sufficiently well known), a new service, a reduction in service to lower costs in order to take advantage of a high fare elasticity in a market, or vice versa for a market with a high service elasticity.

While there are insufficient data to develop market-by-market strategies for Oregon, the most productive approaches may be speculated. Certificated carriers have abandoned some Oregon markets and indicated a desire to abandon others. Therefore, it is reasonable to assume that these markets have not received much recent attention from the certificated carriers' marketing departments. (Particularly since deregulation has required them to pay much closer attention to their most profitable markets.) Hence, new fares, services, and promotions may be very productive, i.e., it may be possible to get these markets producing in the upper tails of the probability distributions that have been developed, or beyond. On the other hand, the successful third-level airlines used to generate the cost distributions have been paying close attention to costs and much smaller gains may be available from cost cutting.

All this is to say that, while the methodology may be quite correct, a nimble management must be able to react to specific problems and potentials; it will inevitably know more after thirty days of operation, about the markets and the circumstances under which it must serve them, than after thirty years of analysis.

SPECIFIC

1. "Frequency factor" effectively represents air mode frequency, the difference in travel time between air and auto modes, and the variation of air travel demand throughout the day. Because it combines three variables into one, it is particularly useful with small data bases. Its greatest utility is in short-haul. (Section 2.5)

2. The "product of the income-weighted taxable income distributions multiplied by the population products" effectively represents

population, area income, and the distribution of area income. Because it combines three variables into one, it is particularly useful with small data bases. Its utility is greatest in markets where the marginal cost of air travel is high, e.g., short-haul. (Section 2.5)

3. Short-haul air travel is more sensitive to the quality of service than to price. Quality of service is represented by frequency factor and reliability in the intra-Oregon travel demand model. Frequency factor performed best when used with the daily demand profile having the least variation throughout the day. This indicates frequency is more important than time of departure. Reliability is important in intra-Oregon travel because of its large exponent (log-log model). The passenger must be assured of completing his air journey as planned or he will choose a competing mode. (Section 2.5)

4. Connecting travel and air freight demand are most sensitive to completed departures illustrating the importance of frequency and reliability in short-haul, even for connecting travelers or air freight. (Section 2.6 and Section 2.7)

5. The Swearingen Metro II should be selected for a single-aircraft fleet serving Oregon. (Section 3.6)

6. Third-level airline costs that can be described by regression analysis have revenue-passenger-miles as the most important independent variable. (Section 3.)

7. The regression equations for third-level airline costs do not indicate that any economies of scale exist in the third-level industry. (Section 3.)

8. An airline with the Oregon airline's cost-revenue structure per aircraft should have one reserve aircraft if it operates a fleet of from five to eighteen aircraft. (Section 4.4.2)

9. Turnaround time is more important than failure rate in determining the number of spare engines required by airlines operating approximately 20000 hours per year. (Section 4.4.4)

10. A Rate-Per-Hour-Contract for engines is only effective with an exchange agreement because turnaround-time, not failure rate, controls the number of spares required. For three airlines pooling spares, each airline should realize a NPV of $115275 through an overhaul shop or a NPV of $68658 through the manufacturer, if all parties have a 13% average-weighted cost of capital. The difference between the overhaul shop and the manufacturer is that the contribution of each spare saved is assumed returned to the manufacturer. (Section 4.5.1)

11. Third-level airlines operating less than 15228 hours a year should contract avionics repair and those operating more should consider setting up their own shop (13% average-weighted cost of capital, Collins Pro-Line Avionics). (Section 4.5.2)

12. If the airline is too small to operate its own avionics shop it should be able to negotiate a Rate-Per-Hour-Contract of ($2.0661 + ($1608/Annual Flight Hours)) per flight hour with an exchange agreement and $2.0661 per flight hour without an exchange agreement. For an airline operating over 15228 hours per year, the rate-per-hour cost should be (($22960/Annual Flight Hours) + $0.4774) per hour. (While the numbers given are exact, they only represent an area of negotiation.) (Section 4.5.2)

13. There are equitable methods for establishing reliability guarantees that can account for the cost of capital and even reward the manufacturer for reliability above that guaranteed. (Section 4.6)

14. There are ten Oregon stations (eight of which are exclusive to the third-level carrier) and fourteen Oregon routes (twelve of which have a positive contribution) that can be profitably served by a third-level carrier. (Section 5.4)

15. A sufficient number of connecting passengers are delivered to Medford (127 outbound passengers per day in 1978) by the third-level airline to make it attractive for a certificated carrier to meet the flights of the third-level airline at Medford four times a day. (Section 5.4.7)

16. "Optimum Coverage" is an effective use of risk analysis to determine the optimum amount of financial resources a firm should have available before commencing a project. (Section 6.3.3.1)

17. In order to begin operations with a minimum amount of capital, third-level airlines should plan on beginning flight operations in October-November. This assumes that a new operation takes four months to start up all routes. (Section 6.3.4.4)

18. If scheduled flights begin in October-November, the airline in Oregon requires $6 million dollars to start up if it is operated as a tax shelter or purchases its own aircraft; it requires $4.7 million dollars if it leases aircraft and retains the investment tax credit; and it requires $4.2 million dollars if it leases the aircraft and the lessor retains the investment tax credit (by the method of optimum coverage). (Sections 6.3.3.1 and 6.3.4.4)

19. In Oregon, the third-level airline simulation yielded mean internal rates of return of 62.2% for the airline as a tax shelter including its benefits to the parent firm, 25.2% for the airline as a tax shelter exclusive of the benefits to the parent firm, 32.3% when the airline purchased its own aircraft, 45.6% when it leased the aircraft, but retained the investment tax credit, and 57.5% when it leased the aircraft and the lessor retained the investment tax credit. (Section 6.3.5.3)

20. A new third-level airline in Oregon is best operated as a tax shelter. If this cannot be arranged, and its average-weighted cost of capital exceeds 2.0%, it should trade as many tax benefits as possible for better financial terms. (Section 6.3.5.3)

AREAS FOR FURTHER RESEARCH

1. The shape of the persistence of demand function should be investigated as to its precise shape, not only as a function of the perceived difference in the travel time between modes, but also how it varies for a passenger having to advance his journey as opposed to one who must delay it and how this varies throughout the day. (Section 2.5)

2. The weighting factor, γ, used in determining PIM may have a value different from two (2). It may be inversely proportional to time savings or distance, making the regression equation nonlinear. (Section 2.5)

3. A larger data base for third-level airline costs should lead to better forecasting equations and explain cost components that this study was unable to explain, e.g., number of mechanics, maintenance burden. (Section 3.)

4. The initial traffic as a percentage of mature demand and how it builds to mature demand, by type of service, route, type of equipment, etc., is extremely important in determining early cashflows. U. S. air carriers were unable to provide a quantitative analysis of what appears to be a very important process. (Section 6.3.2.3)

5. There is no published quantitative analysis of aircraft reliability with time. Aircraft reliability as a function of in-service time with a new operator and the effects of other operators having previous experience on the type should be investigated. (Section 6.3.2.4)

6. The results of the weighted random walks are more closely grouped than recent experience; this should not be the case. No statistically significant correlations were found between time periods in this study, but these correlations, which could lead to a moving average model that yields more realistic results, may still exist. Preferably a larger data base could be found and investigated, or a lower level of statistical significance could be accepted, a less satisfactory solution. (Appendix C)

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APPENDIX A

MULTIPLE REGRESSION ANALYSIS

A1. INTRODUCTION

Regression equations are explanatory, statistical models that attempt to generate new information through simulation. The technique discussed is "The Method of Least Squares" and was developed by the French mathematician Adrian Legendre in the 19th century. The Least Squares criterion requires that the sum of the squares of the deviations of the observations from the fitted line be a minimum. The following discussion is extensively adapted from "Econometric Models and Economic Forecasts" by Robert S Pindyck and Daniel L Rubinfeld[79] except where noted.

A1.1 TYPES OF REGRESSION MODELS

Cross-Sectional models deal with real world *causal* relationships, either directly or via an exogenous factor, and,as such,use data from one time period only.

Time-Series models presume nothing about real world causal relationships but, instead, examine past behaviour of a time series in order to explain the changes over time.

Pooled Models attempt to combine both real world relationships and time-series data to help in predicting both within a time period (cross-sectionally) and into the future.

Multi-equation Simulation Models use regression equations to predict independent variables for other regression equations and as such presume to explain a great deal about the structure of the physical process being studied.

A1.2 THE BASICS OF REGRESSION ANALYSIS

Suppose we have a set of observations of a dependent variable and independent variables in a linear equation of the form:

$$Y = \beta_1 + \beta_2 X_2 + \beta_3 X_3 + ... + \beta_m X_m \tag{1}$$

where Y is the dependent variable and X_2, X_3, ... X_m are the independent variables and the coefficients β_1, β_2 ..... β_m are to be determined. The set of observations is defined by subscripts 1, 2, ..., i, j, ..., n and the included independent variables by subscripts 2, 3, ..., p, q, ... m.

The observed value of Y, Y_i for the i^{th} observation, differs from the computed value $\hat{Y}_i$, by some error term $\hat{e}_i$. The value of the coefficients $\beta_1, \beta_2, ... \beta_p, \beta_q, ... \beta_m$ are estimated given the observed values of of Y_i and $X_{i2}, ... X_{ip}, X_{iq}, ... X_{im}$.

An equation of the form

$$\hat{Y}_i = \hat{\beta}_1 + \hat{\beta}_2 X_{2i} + ... + \hat{\beta}_p X_{pi} + \hat{\beta}_q X_{qi} + ... + \hat{\beta}_m X_{mi} + \hat{\epsilon}_i$$

is assumed where the $\hat{\beta}_s$ estimate the true β_s and $\hat{\epsilon}_i$ is the difference between the observed value (Y_i) and estimated value ($\hat{Y}_i$) of the dependent variable for the ith observation, $\hat{e}_i = (Y_i - \hat{Y}_i)$. Thus the deviations are measured orthogonally from the plane(s) of the independent variable(s). The goal is now to find the coefficients which minimise the sum of the squares of $\hat{e}_i$ which is implicit in

$$\text{Minimise} \quad \sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2 = \sum_{i=1}^{n} (\hat{e}_i)^2$$

(Σ shall imply $\sum_{i=1}^{n}$ unless otherwise noted)

If the means of the variables are defined:

$$\bar{Y} = \Sigma Y_i / N \qquad \bar{X} = \Sigma X_i / N$$

It is now possible to calculate the regression coefficients which will minimise $E(\epsilon_i)$, where E( ) is the expected value of ( ). Starting first with the two-variable case, where it is customary to represent β_1 by α and β_2 by β.

$$\hat{\beta} = \frac{\Sigma (X_i - \bar{X})(Y_i - \bar{Y})}{\Sigma (X_i - \bar{X})^2}$$

and

$$\hat{\alpha} = \bar{Y} - \hat{\beta} \bar{X}$$

For the equation with three independent variables we need:

$$\frac{\partial \Sigma (\epsilon_i^2)}{\partial \beta_{1,2,3}} = 0$$

For

$$\hat{Y}_i = \hat{\beta}_1 + \hat{\beta}_2 X_{2i} + \hat{\beta}_3 X_{3i} + \epsilon_i$$

which, defining

$$y_i = (Y_i - \bar{Y}),\ x_{2i} = (X_{2i} - \bar{X}_2),\ \text{and } x_{3i} = (X_{3i} - \bar{X}_3)$$

yields

$$\beta_1 = \bar{Y} - \beta_2 \bar{X}_2 - \beta_3 \bar{X}_3$$

where

$$\beta_2 = \frac{(\Sigma x_{2i} y_i)(\Sigma x_{3i}^2) - (\Sigma x_{3i} y_i)(\Sigma x_{2i} x_{3i})}{(\Sigma x_{2i}^2)(\Sigma x_{3i}^2) - (\Sigma x_{2i} x_{3i})^2}$$

$$\beta_3 = \frac{(\Sigma\, x_{3i}\, y_i)(\Sigma\, x_{2i}^2) - (\Sigma\, x_{2i}\, y_i)(\Sigma\, x_{2i}\, x_{3i})}{(\Sigma\, x_{2i}^2)(\Sigma\, x_{3i}^2) - (\Sigma\, x_{2i}\, x_{3i})^2}$$

For higher order cases it is necessary to go to matrix notation.

$$\beta_3 = (X'\,X)^{-1}\,(X'\,Y)$$

where

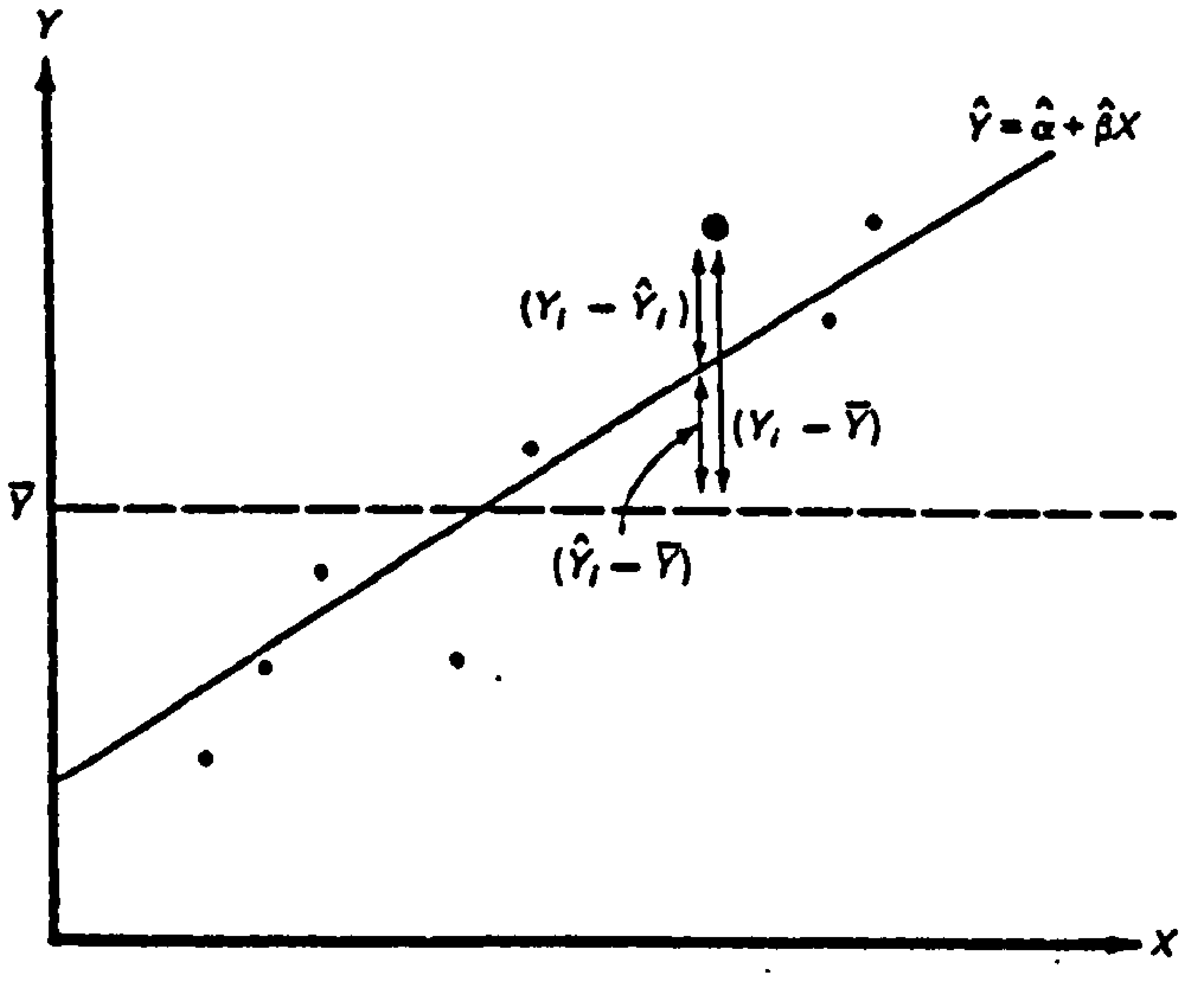
- X is a matrix N X M, the value of the independent variables.
- Y is a matrix of N X 1, the value of the dependent variables.
- X' is the transpose of X
- $X'X$ is the cross-product matrix guaranteed to have an inverse, $(X'X)^{-1}$, because X has rank M which yields the nonsingularity of $X'X$.

For:

$$\frac{\delta\, \Sigma\, \epsilon_i^2}{\delta\, \beta_{1,2,\ldots,m}} = 0$$

The graphical representation of the two-dimensional situation is shown in Figure 1.

FIGURE A-1
Decomposition of Y_i



The above is subject to the following assumptions:

1. X and Y have a "linear" relationship as shown in equation (1).
2. (i) X_i's are nonstochastic and no exact linear relationship exists between them, i.e. $E(X_p\, X_q) = 0$

   (ii) Y_i's are the stochastic variables

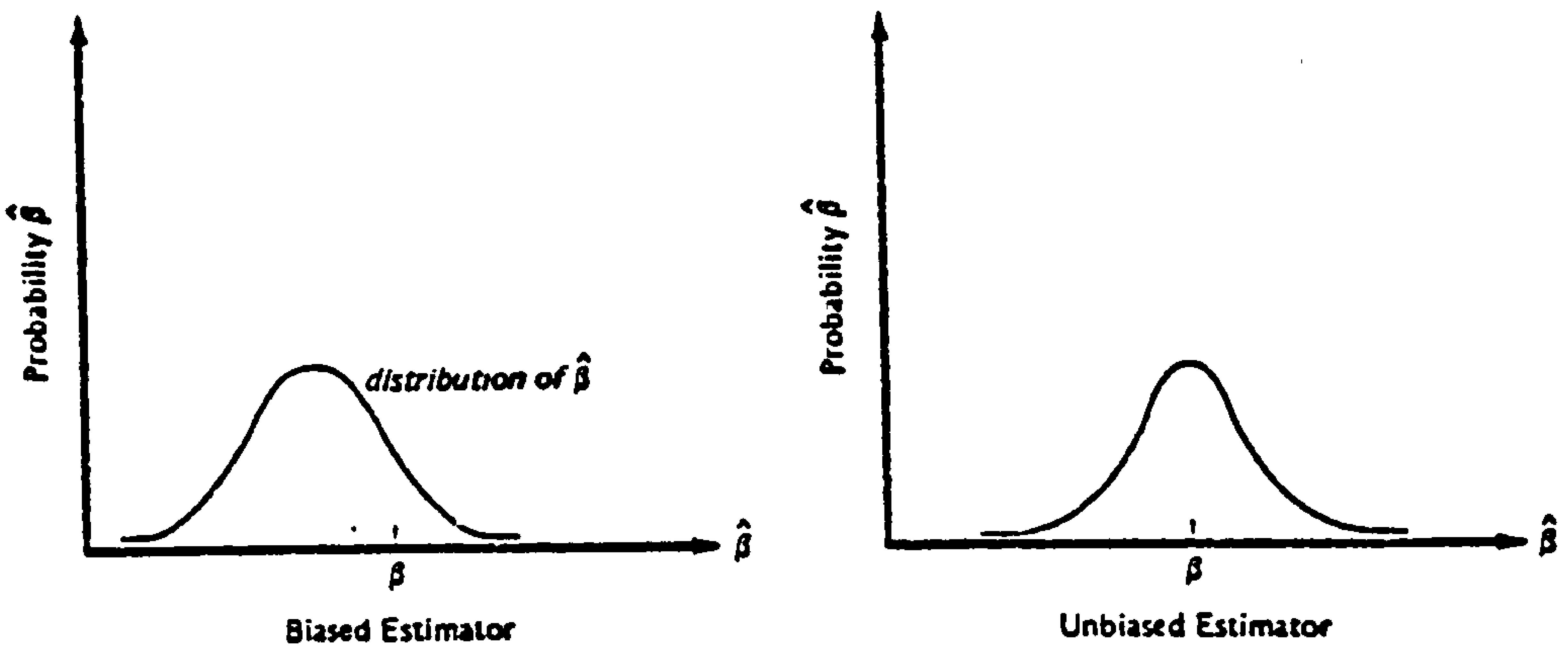
3. (i) The error term (ϵ_i) has zero expected value and constant variance for all observations; i.e. $E(\epsilon_i) = 0$ and $E(\epsilon_i^2) = \sigma^2$.

   (ii) The error terms (ϵ_i) are random variables uncorrelated in a statistical sense; i.e. $E(\epsilon_i \, \epsilon_j) = 0$.

   (iii) The error term (ϵ_i), after linearisation, is normally distributed.

4. Assumption 2 allows us to conclude that $E(X_i \, \epsilon_i) = X_i \, E(\epsilon_i) = 0$ and assumptions 3 (i) and (ii) that $E(\Sigma \epsilon_i) = \Sigma \, E(\epsilon_i) = 0$

FIGURE A-2
Bias



We need these assumptions to ensure that the β's are:

1. *Unbiased* so the mean or expected value of $\hat{\beta}$ is equal to the true value, β, Figure 2.
2. *Efficient* in that the variance of $\hat{\beta}$ is less than that of any other unbiased estimator, Figure 3.
3. *Consistent* so that as the sample size increases the value of $\hat{\beta}$ approaches the true value, β, Figure 4.
4. *Unbiased, efficient* estimators (β_p) ensure minimum mean square error in the model. Where the standard error, s^2, is defined:

$$s^2 = \frac{\Sigma \, \epsilon_i^2}{N-M}$$

FIGURE A-3
Efficiency

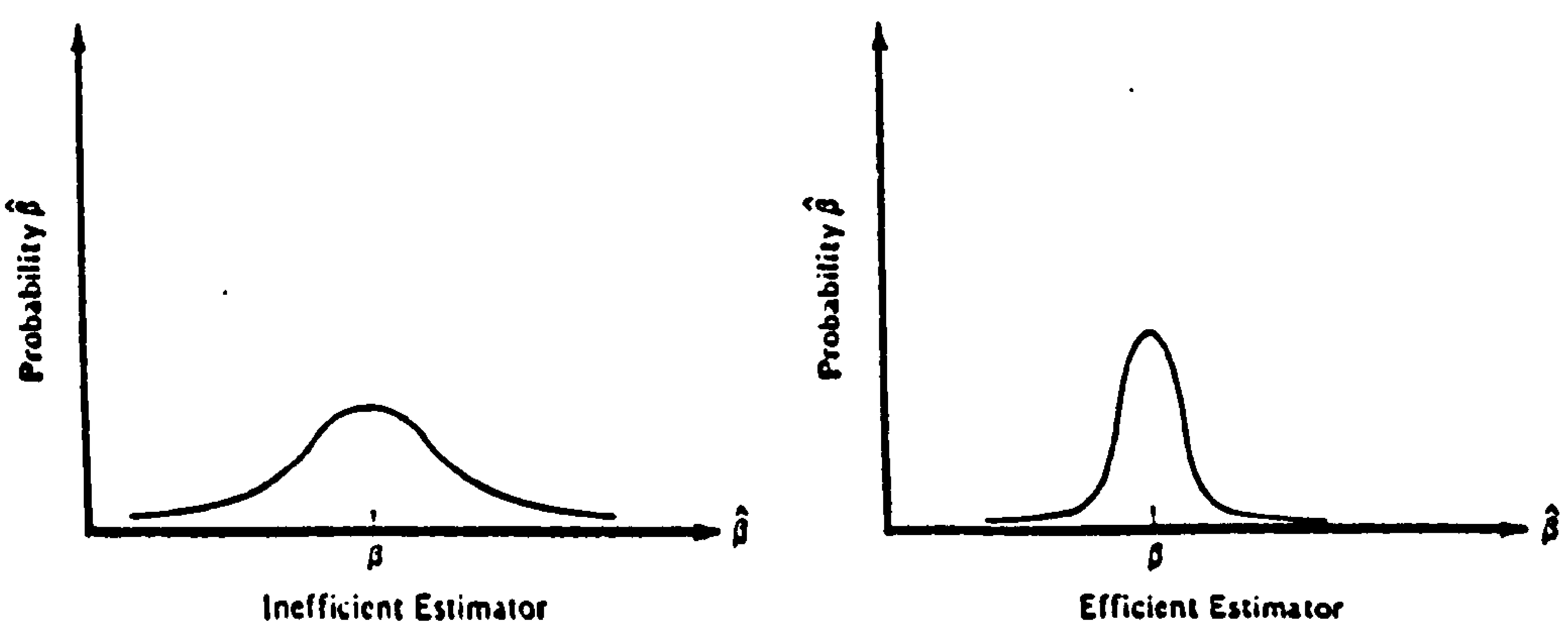
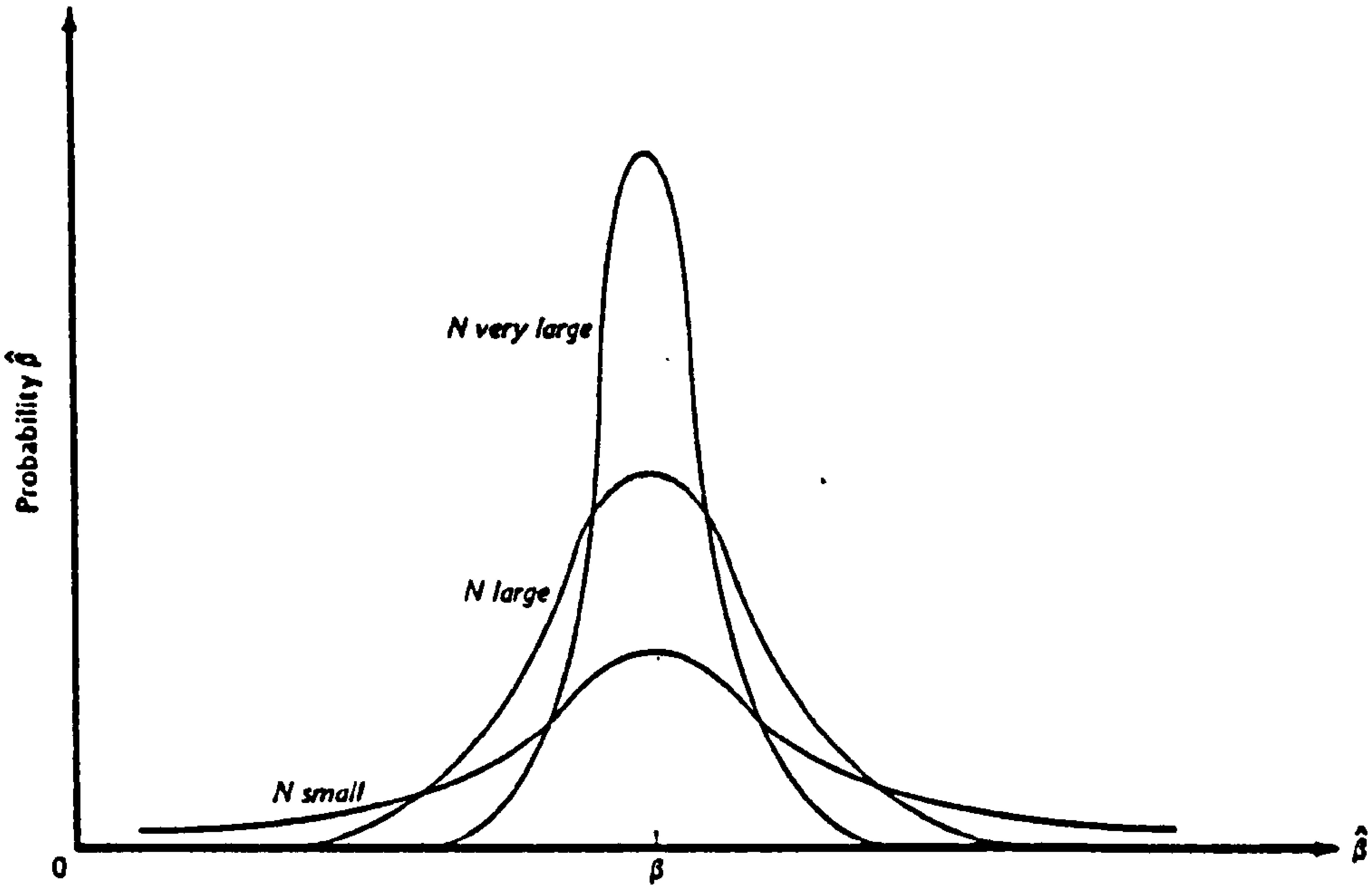
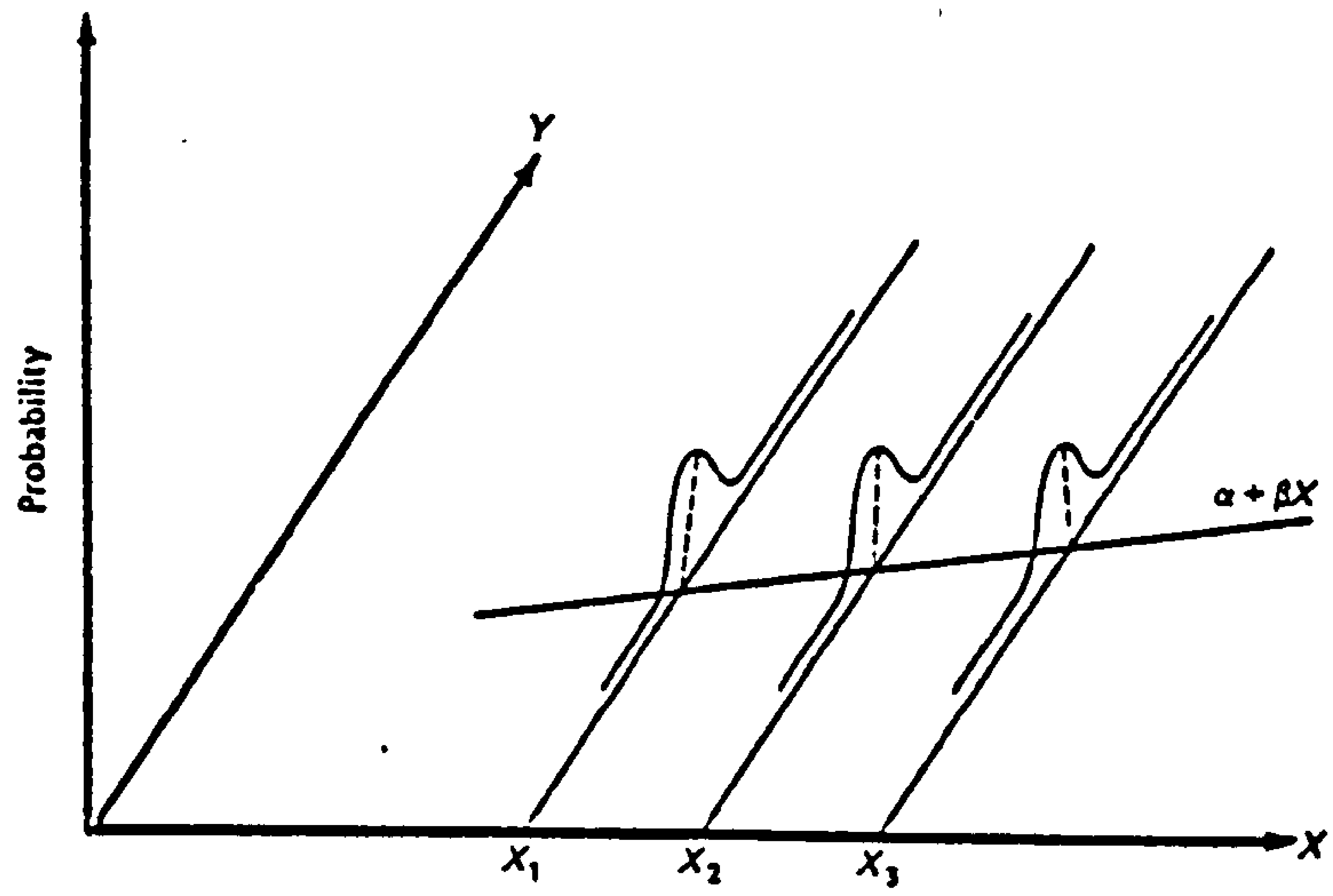


FIGURE A-4
Consistency



The minimum mean square error combined with *consistency* ensures that new estimates (simulations) by the model will be the most accurate possible. If the above all hold then we have the best possible fit with the errors of estimate normally distributed about the fitted line as shown in Figure 5.

FIGURE A-5
Two-variable regression model



A2. LINEARISATION OF EQUATIONS

The above implies, quite correctly, that the regression must be linear in form Eqn (1). This restriction only means in practice that equations need be *inherently linear* as *inherently linear equations* can be expressed in a *linear form* by a proper transformation. A model is inherently linear iff:

$$F(Y) = \beta_2\gamma_2(X_2, \ldots\ldots, X_m) + \ldots + \beta_m\gamma_m(X_2, \ldots, X_m) + \epsilon$$

or

$$Y^* = \beta_2 X_2^* + \beta_x X_3^* + \ldots + \beta_m X_m^* + \epsilon^* \quad (2)$$

The functions of F and γ_2 through γ_m must be known and the essential relationship that (2) is linear with respect to its coefficients $\beta_{2,3....m}$ obtained.

A2.1 TESTING FOR LINEARITY

If the sample of N observations is broken into G groups where each group has a single distinct value of X, X_g, then by definition

$$N = \sum_{g=1}^{G} N_g$$

and defining

Y_{gi} = the i value of the random variable Y_g

Y_g = the sum of the values of Y_g in the example.

Then computing

$$f = \frac{D_1^2 \, (N-G)}{D_2^2 \, (G-2)}$$

where

$$D_1^2 = \sum_{g=1}^{G} \frac{Y_g^2}{N_g} - \frac{(\Sigma \, Y_{gi})^2}{N} - \left[\frac{N \, \Sigma \, X \, Y - \Sigma \, X \, \Sigma \, Y}{N \, \Sigma \, X^2 - (\Sigma X)^2}\right]^2 \left[\frac{\Sigma \, X^2 - (\Sigma \, X)^2}{N}\right]$$

and

$$D_2^2 = \Sigma \, Y_{gi}^2 - \sum_{g=1}^{G} \frac{Y_g^2}{N_g}$$

Now f is a value of the random variable F, having an F distribution with G−2 degrees of freedom in the numerator and N−G degrees of freedom in the denominator. The distribution is not linear when the f value falls in the upper tail of the F distribution.

Some of the more popular linearisations are[80]:

I Polynomial Model

$$Y = \beta_1 + \beta_2 X_2 + \beta_3 X_2^2 + ... + \beta_m X_2^{m-1} + \epsilon$$

II The Multiplicative Model

where $Y = \gamma_1 X_2^{\gamma_2} \, X_3^{\gamma_3} \, ...X_m^{\gamma_m} \, \epsilon *$

which when transformed becomes

$$\text{Log}_e Y = \text{Log}_e \gamma_1 + \gamma_2 \text{Log}_e X_2 + \gamma_3 \text{Log}_e X_3 + \ldots. + \gamma_m \text{Log}_e X_m + \epsilon$$

because $\epsilon = \text{Log}_e\ \epsilon^*$ the distribution of ϵ^* will not be normal but lognormal. Considering

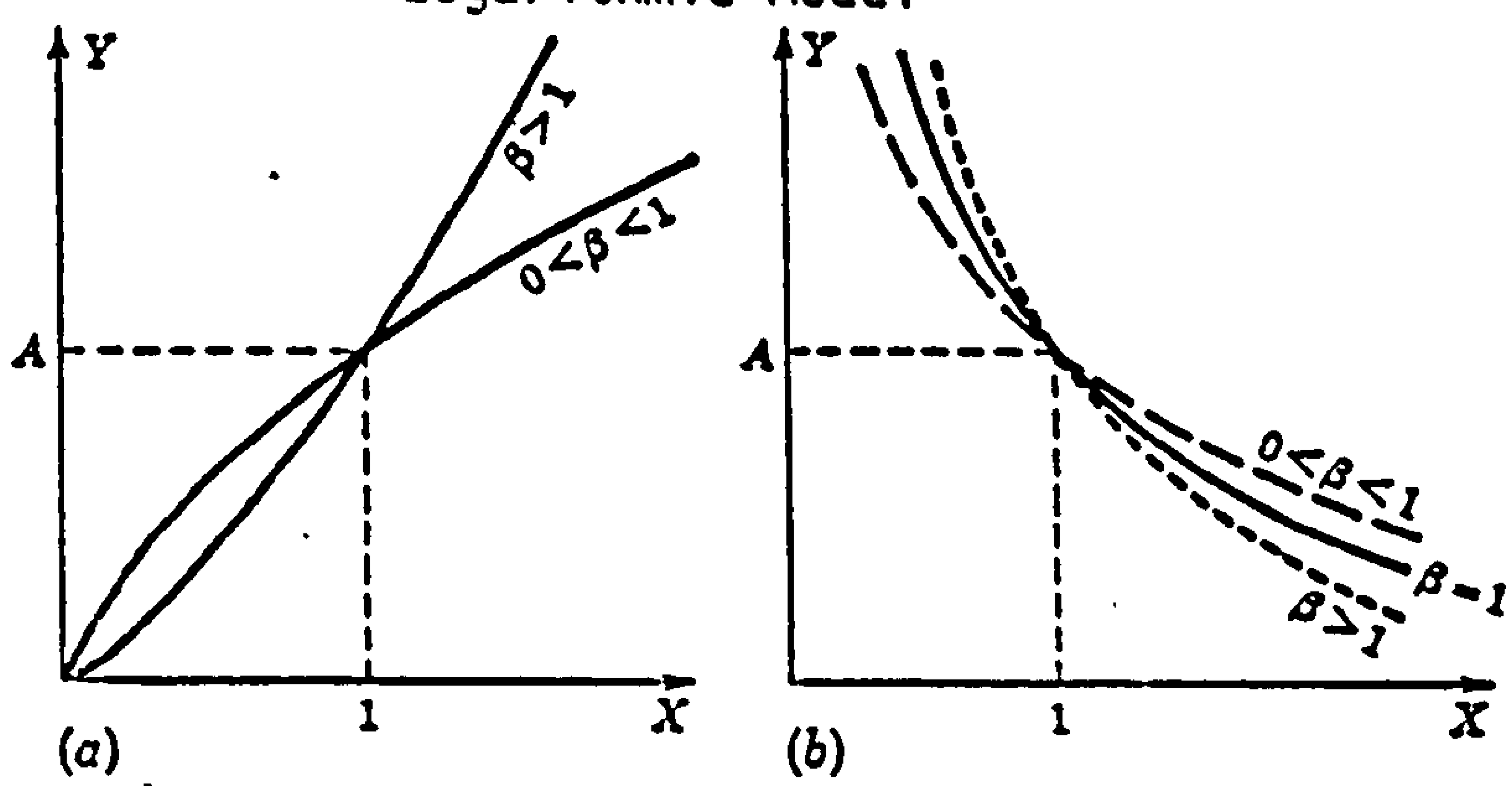
$$\text{(a)}\quad Y = AX^{\beta} \qquad \text{and (b)}\quad Y = AX^{-\beta}$$

where $\text{Log}_e A = \alpha$ and when (a) and (b) are rewritten they become:

$$\text{(a)}\quad \text{Log}_e\ Y = \alpha + \beta\ \text{Log}_e X \qquad \text{and (b)}\quad \text{Log}_e Y = \alpha - \beta\ \text{Log}_e X$$

which graph as Figure 6 (a) and (b) respectively.

FIGURE A-6 Logarithmic Model



III The Reciprocal Model

$$Y = \frac{1}{\beta_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots.. + \beta_m X_m + \epsilon}$$

which when transformed becomes:

$$\frac{1}{Y} = \beta_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots. + \beta_m X_m + \epsilon$$

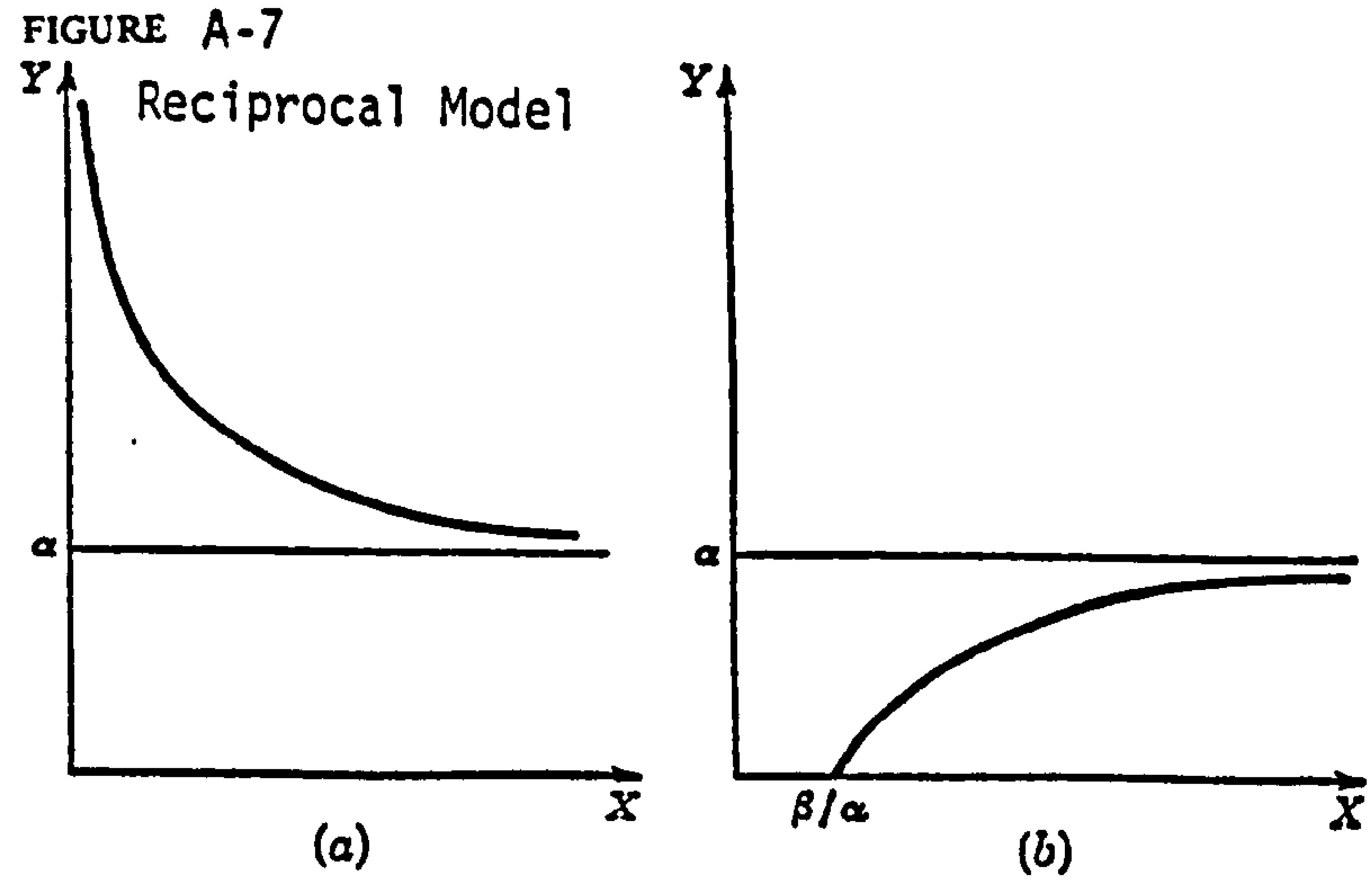
or in the two variable case:

$$\text{(a)}\quad Y = \alpha + \beta/X \qquad \text{or (b)}\quad Y = \alpha - \beta/X$$

which plots as in Figure 7 (a) and (b) respectively.

FIGURE A-7

Reciprocal Model



IV The Semilog Model

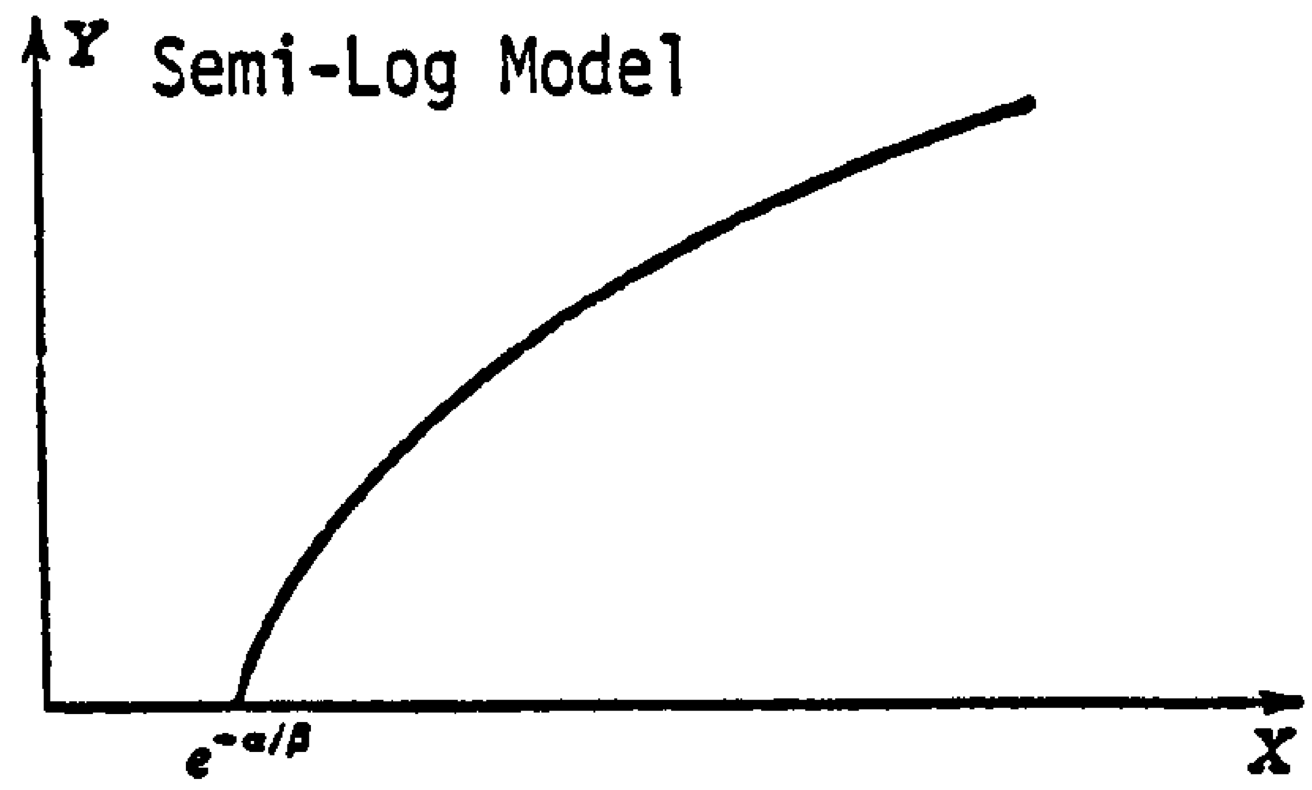
$$Y = \beta_1 + \beta_2 \operatorname{Log}_e X_2 + \dots + \beta_m \operatorname{Log}_e X_m + \epsilon$$

which again for the two variable case becomes:

$$Y = \alpha + \beta \operatorname{Log}_e X \qquad \text{or } X = \alpha \beta^Y$$

and plots as in Figure 8.

FIGURE A-8



V The Exponential Model

$$Y = \exp(\beta_1 + \beta_2 X_2 + \dots + \beta_m X_m + \epsilon)$$

which transforms into

$$\operatorname{Log}_e Y = \beta_1 + \beta_2 X_2 + \dots + \beta_m X_m + \operatorname{Log}_e \epsilon$$

VI The Reciprocal Logarithmic Model

$$Y = \exp(\beta_1 + \beta_2/X_2 + \dots + \beta_m/X_m + \epsilon)$$

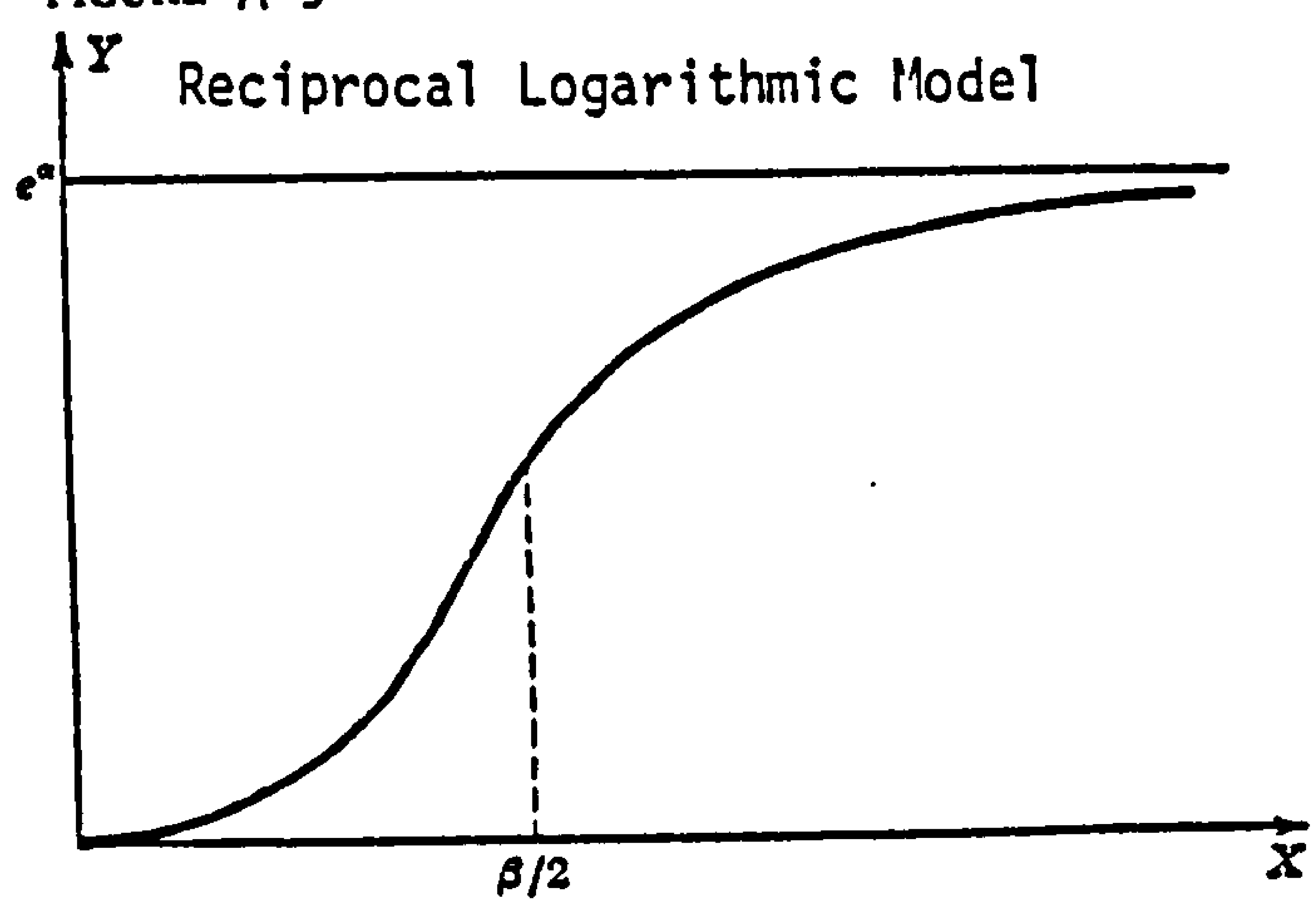
which can be transformed into:

$$\operatorname{Log}_e Y = \beta_1 + \beta_2/X_2 + \dots + \beta_3/X_3 + \epsilon$$

and can be graphed for the two variable case as in Figure 9 when

$$\operatorname{Log}_e Y = \alpha + \beta/X \text{ and } \beta < 0.$$

FIGURE A-9



It is imperative that all statistical tests apply to the model in the *linear, transformed state* and not after it has been inverted into the *inherently linear, untransformed state.*

It may be tempting to do scatter diagrams between each independent variable and the dependent variable to get the form of the equation by inspection. This method, provided the *causal* relationship is justified, works for a simple regression equation with only one independent variable. However, as soon as the first variable is added, the relevant plot is the second independent variable against the residuals from the first regression and so on for successive independent variables. It does not take much imagination to see that the order of adding variables may significantly affect the form of an equation derived in this manner if the *causal* relationship is disregarded.

A3. PROBLEMS OF REGRESSION ANALYSIS

A3.1 CORRECT SPECIFICATION

Regression analysis fits lines to data;it does not think. The onus is on the analyst to ensure that the cause and effect indicated is truly representative of the real world situation.

A3.2 MISSING VARIABLES

A missing independent variable will increase the standard error of estimate, the magnitude of the error being proportional to the importance (beta-coefficient) of the variable . If the missing variable is correlated with an included independent variable it will be *biased*; if not, it will remain *unbiased.*

A3.3 SPURIOUS CORRELATION

Spurious correlation occurs when a variable is included and correlated but not *causal* to the dependent variable. A spurious variable will cause a loss of *efficiency* and *bias* the coefficient of any independent variable with which it is correlated. The solution is to review the *causal* organisation of the model and eliminate the spurious variable.

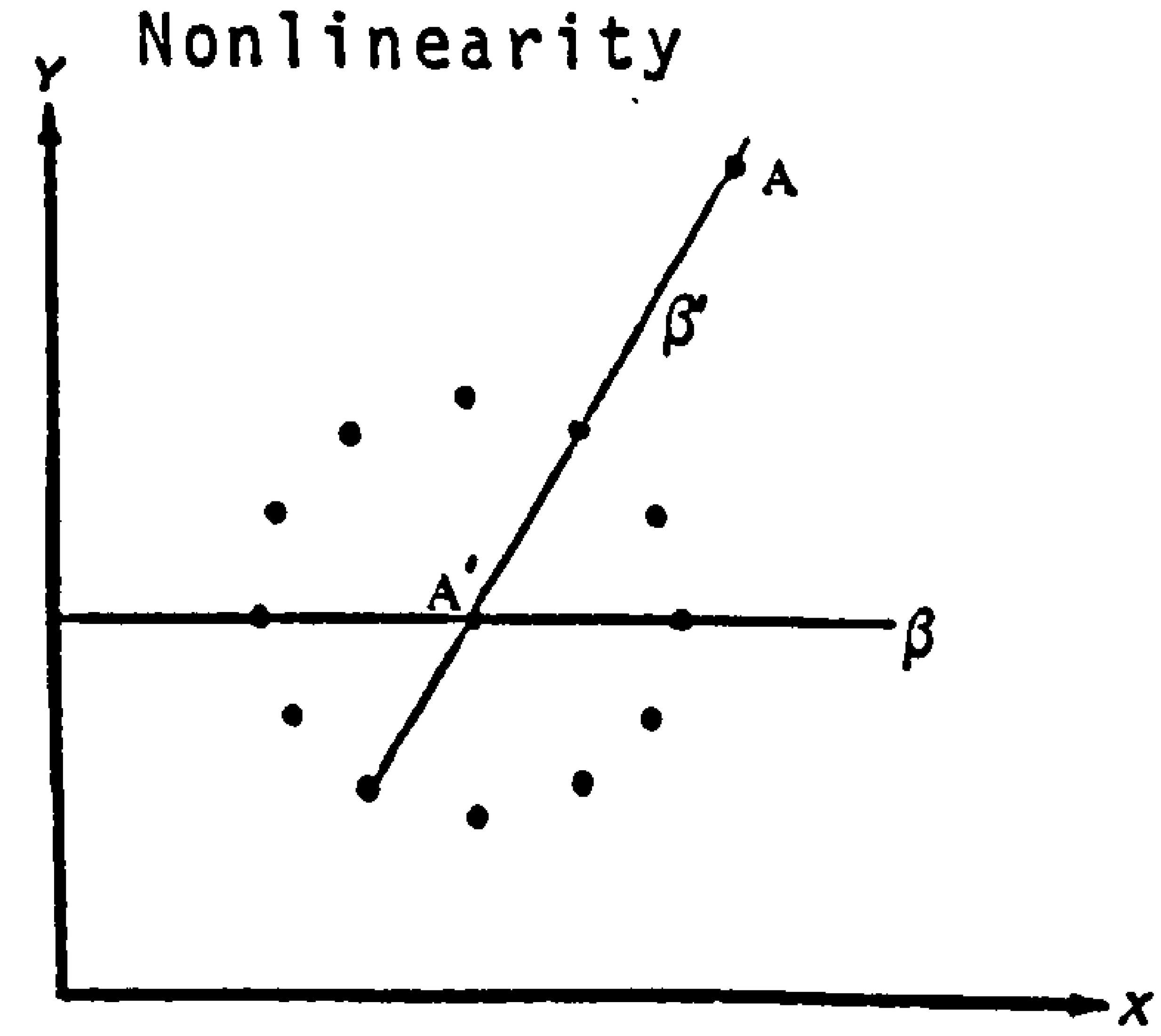
A3.4 ERRORS IN THE DATA

Errors in observation of either the dependent or the independent variables are obviously important and if doubts exist checks against other sources should be made.

A3.5 THE SINGLE SIGNIFICANT OBSERVATION

Suppose we have a set of observations giving the circle in Figure 10 which yields the regression line β and then a further observation is obtained. If the observation is at A we get the regression line β' which now appears explanatory ($\beta' \neq 0$). But suppose the single observation had been at A' then line β would have remained valid. The point is that though several degrees of freedom are available, it would be wrong to allow one or even relatively few observations to determine the equation. If in doubt, the observations should be tested for linearity.

FIGURE A-10
Nonlinearity



A3.6 INSTRUMENTAL VARIABLES

Instrumental variables are *proxies* for the intended independent variable when the intended variable is correlated with either another independent variable or the residuals of the equation. They are variables which have a *causal* relationship to the dependent variable similar to the variable they replace and are highly correlated with the variable they replace, but are not correlated with other independent variables or the residuals. Alternatively, the correlated independent variable may be combined with one of the other independent variables in a linear fashion to eliminate the troublesome correlation.

A3.7 MISSING OBSERVATIONS

The problem of missing or *a priori* erroneous observations often occurs in model building. There is no single best approach to this problem and no substitute for careful thought on the part of the analyst. The observation may best be discarded in a two variable, single-stage model but the more complex the model the more applicable, and perhaps necessary, the techniques become.

1. Dropping observations results in a loss of efficiency if the missing observations occur at random. If the missing observations are associated with a particular class and they are dropped, the resulting coefficient, $\hat{\beta}_p$, may be biased.

2. If there is *a priori* knowledge of what the missing variables should be, these should be substituted.

3. If no *a priori* knowledge is available, $\bar{X}_p$, could be assigned to the variable, which is equivalent to regressing X on a constant and assigning each missing observation the estimated coefficient. The result does not improve the estimate of β_p, $\hat{\beta}_p$, or its variance but may change other coefficients with which X_p is correlated, and improve their efficiency.

4. *Solving* for L missing observations necessitates increasing the resulting standard error by

$$\left[\frac{N-1}{N-L-1}\right]^{1/2}$$

to compensate for the added artificial efficiency.

A3.8 IDENTIFICATION

The first step in formulating an econometric model is development of a structural model which shows an accurate *causal* relationship between the dependent variables. It is necessary to the development of this model that it can confidently be stated that the dependent variable is actually caused by the independent variable and not the reverse. *Such an assumption is inherent to the problem and undiscernible from statistics;* regression statistics, for example, will be identical in the two variable model when the variables are reversed. Though the regression coefficients will usually be different.

Once a structural model has been specified it is necessary to check whether its equation(s) are identified. An equation(s) is identified if it is possible to obtain values of the parameters from the reduced form of the equation system, exactly identified if a unique parameter exists (linearly independent equations), over-identified if more than one value is obtainable for some parameters, and under-identified where there is no way of estimating all the structural parameters from the reduced form.

First explicit intercepts are eliminated by:

$$x_{ip} = X_{ip} - \bar{X}_p$$

Now consider

Structural Model:

$$y_i = \alpha_2 + x_{ip} + \epsilon_i \tag{3}$$

$$y_i = \beta_2 x_{ip} + \beta_3 x_{iq} + \beta_4 x_{ir} + u_i \tag{4}$$

Reduced Form Model:

$$y_i = \frac{\alpha_2 \beta_3}{\alpha_2 - \beta_2} x_{iq} + \frac{\alpha_2 \beta_4}{\alpha_2 - \beta_2} x_{ir} + \frac{\alpha_2 u_i - \beta_2 \epsilon_i}{\alpha_2 - \beta_2}$$

$$y_i = \pi 1_2 x_{iq} + \pi 1_3 x_{ir} + v 1_i \tag{5}$$

$$x_{ip} = \frac{\beta_3}{\alpha_2 - \beta_2} x_{iq} + \frac{\beta_4}{\alpha_2 - \beta_2} x_{ir} + \frac{u_i - \epsilon_i}{\alpha_2 - \beta_2}$$

$$x_{ip} = \pi 2_2 x_{iq} + \pi 2_3 x_{ir} + v 2_i \tag{6}$$

Equation (5) is overidentified, two independent variables instead of one, therefore it is necessary to utilise the *two-stage, least-squares* procedure. Ordinary least squares is applied to equation (6). The resulting estimated value of x_{ip}, $\hat{x}_{ip}$ is then substituted as an instrument in equation (3) and a second ordinary least-squares regression is run. The resulting y_i will be *consistent*. Strictly speaking, $\hat{x}_{ip}$ will be independent of u_i and ϵ_i only for large samples so we are forced to rely on the *consistency* property of two-stage least-squares.

A4. TESTING THE INDEPENDENT VARIABLES

It is necessary to test for the significance of each of the independent variables in the regression equation. The most widely used test for this purpose is the student's t–test which tests the likelihood that $\beta = 0$, or, in other words, that the independent variable X_p offers no explanation of the dependent variable Y.

The t–test is given by:

$$t_{p,N-M+1} = \frac{\Sigma (X_{ip} - \bar{X}_p)(Y_i - \bar{Y})}{\left[\dfrac{\Sigma (X_{ip} - \bar{X}_p)^2 \, \Sigma \hat{\epsilon}_i^{\,2}}{N-M}\right]^{1/2}}$$

Generally, this is checked at a confidence level of 95 per cent with the use of standard tables. Once the t–statistic is obtained it can be used to test for other problems in regression analysis. The t–statistic is related to the standard error of estimate of the independent variable, thus:

$$t_{p,N-M+1} = \frac{\hat{\beta}_p}{S_{\hat{\beta}_p}} \quad \text{or} \quad S_{\hat{\beta}_p} = \frac{\hat{\beta}_p}{t_{p,N-M+1}}$$

A4.1 MULTICOLLINEARITY occurs when

$$E(X_p X_q) \neq 0$$

Multicollinearity may be thought of as a problem caused by two independent variables being insufficiently independent. In the statistical sense, that one lacks confidence in which variable is explaining which effects. If two collinear variables are included the standard errors of the regression coefficients increase, the t–statistics decrease, with no *bias* on the regression coefficient itself. The alternative of leaving a variable out leads to the problem of a missing variable. A better solution is to combine one of the collinear variables with another variable forming an *instrumental variable* or finding another variable that is highly correlated with the variable being omitted but uncorrelated with the other independent variable(s).

The simplest test for multicollinearity is to add the suspected variable to the equation and see what effect it has on the t–statistics of the other included variables. If the other t–statistics improve so much the better but if some t–statistics decrease there is need for quantitative assessment. A good rule-of-thumb is that the *partial correlation* of the independent variable with the dependent variable should exceed the independent variables *simple correlation* with any other variable, where the *partial correlation coefficient* is the correlation between the independent variable under consideration and the dependent variable when all other dependent variables are included in the equation. In other words, it is the correlation of that variable with the equation's residuals when all variables except the one being tested are included. The *simple correlation* is the correlation between the independent variable and the other independent variables (or the dependent variable) when the effects of the other independent variables are not included.

The partial correlation between an independent variable and the dependent variable is given by:

$$r_{YX_p X_q} = \frac{\Sigma\epsilon_i\, \Sigma(X_{ip} - \bar{X})}{(\Sigma(\epsilon_i^2)\, \Sigma(X_{ip} - \bar{X})^2)^{1/2}} = \frac{t_{p,N-M+1}}{((t_{p,N-M+1})^2 + N + 2)^{1/2}}$$

$$q = 1,2, \ldots, m, \quad q \neq p$$

The simple correlation between two variables is given by:

$$r_{X_p X_q} = \frac{\Sigma (X_{ip} - \bar{X}_p)(X_{iq} - \bar{X}_q)}{(\Sigma(X_{ip}-\bar{X}_p)^2\, \Sigma(X_{iq}-\bar{X}_q)^2)^{1/2}}$$

Should $r_{Y X_p X_q} < r_{X_p X_q}$

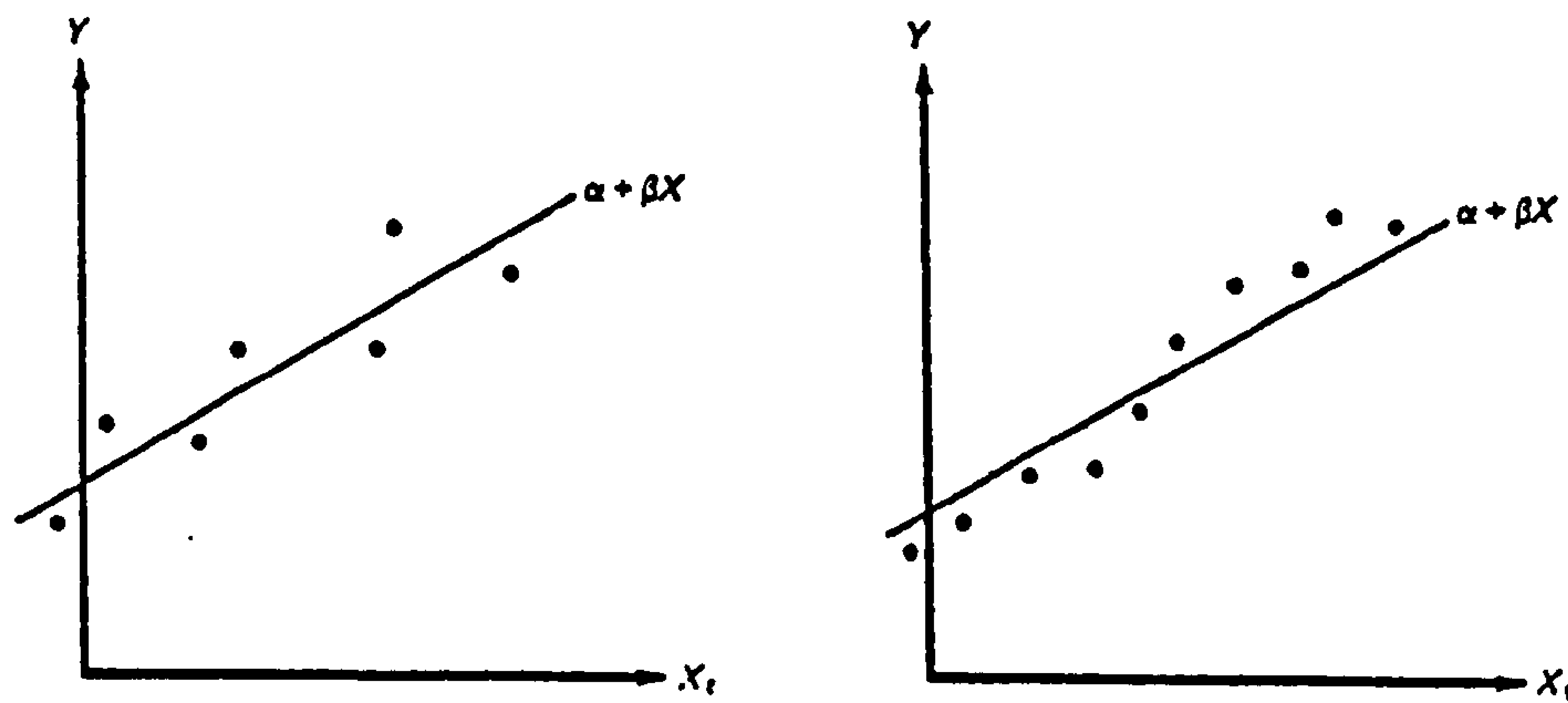
an instrumental approach should be used, failing that, the problems of the missing variable must be accepted.

A4.2 SERIAL CORRELATION or AUTOCORRELATION occurs when

$$E(\epsilon_i \epsilon_j) \neq 0 \text{ for } i \neq j$$

The parameter estimates are *unbiased* and *consistent* but *inefficient*, Figure 11.

FIGURE A-11 Serial Correlation



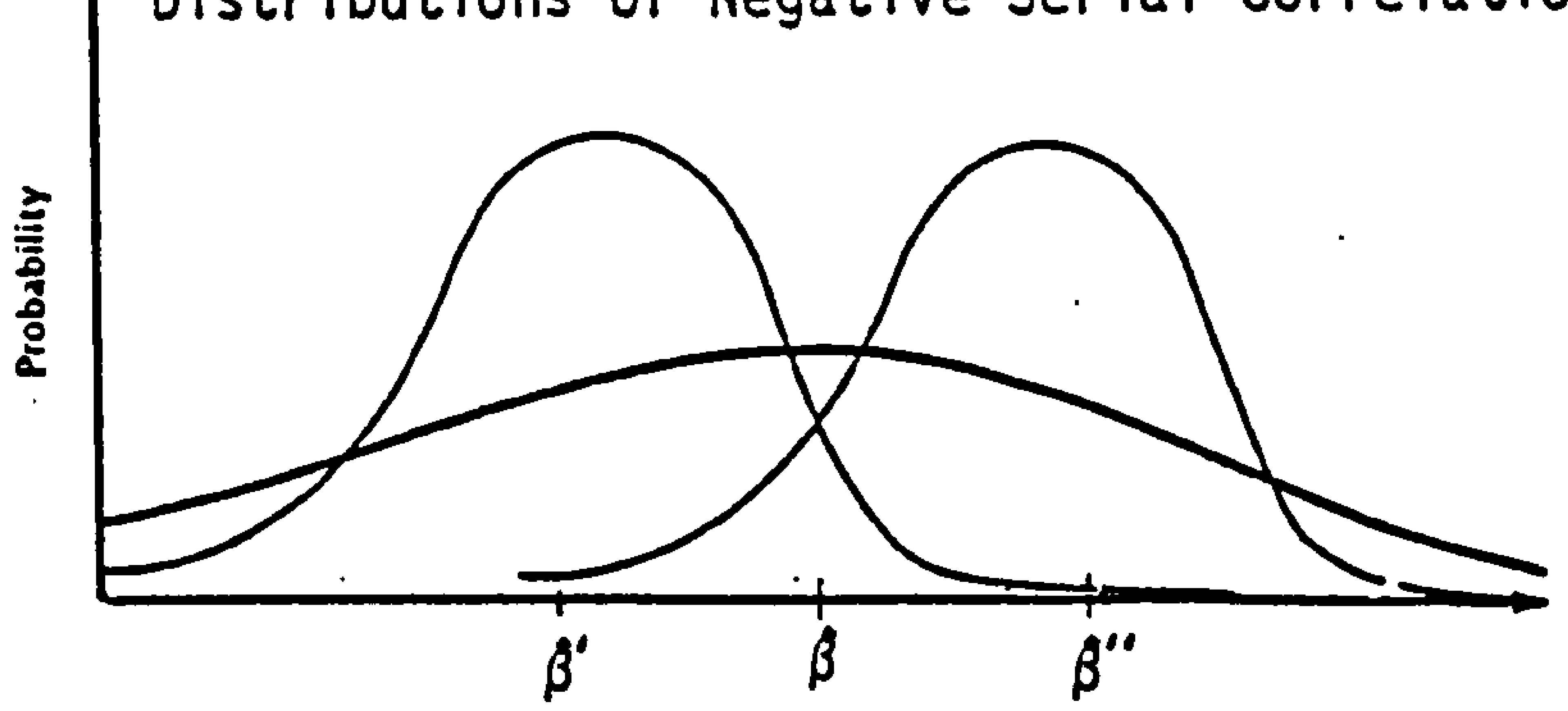
(a) Negative Serial Correlation (b) Positive Serial Correlation

With positive serial correlation the effect is to reduce the estimates of the standard errors leading to a conclusion that the parameter estimates are more accurate than they are in fact. The opposite is true of negative serial correlation. This is because positively correlated residuals give us less information than if they were completely random residuals, similar to reducing the number of degrees of freedom.

With negatively correlated residuals effectively somewhat more information is gained. This may be conceptualised as two adjacent normal distributions, each composed of part of the observations, with much smaller standard deviations than the standard deviation of one large single group and must result in a reduced standard error, Figure 12.

FIGURE A-12

Distributions of Negative Serial Correlation



It should be pointed out that problems with serial correlation are most prevalent in time-series regressions and can generally be attributed to a missing variable(s) or mis-specification of the equation's form; a linear equation fitted to an exponential curve will show serial correlation and vice versa.

There are several tests for serial correlation. All involve computing a coefficient and comparing them against standard tables. Three tests are considered here:

Durbin–Watson Test:

$$DW = \frac{\sum_{i=2}^{n} (\hat{\epsilon}_i - \hat{\epsilon}_{i-1})^2}{\Sigma\, \hat{\epsilon}_i^2}$$

Autocorrelation of Residuals:

$$\rho_{\hat{\epsilon}} = \frac{\sum_{i=1}^{n-1} \hat{\epsilon}_i \hat{\epsilon}_{i+1}}{\sum_{i=1}^{n-1} \hat{\epsilon}_i^2}$$

Von Neumann's Ratio:

$$VNR = \frac{N \sum_{i=1}^{n-1} (\hat{\epsilon}_{i+1} - \hat{\epsilon}_i)^2}{(N-1)\, \Sigma\, \hat{\epsilon}_i^2}.$$

If these tests show significant autocorrelation at the 5% level the standard error should be corrected by the factor

$$\rho_c = (1 + 2\rho_1 + 2\rho_2 + ... + 2\rho_{n-1})^{1/2}.$$

Where the subscript refers to the number of periods the compared residuals are lagged. If we assume that $\rho_2 = \rho_1^2$, $\rho_3 = \rho_1^3$, $\rho_4 = \rho_2^2 = \rho_1^4$, etc. Higher order terms will normally be small and can be ignored; note that this gives the correct value for either positive or negative autocorrelation.

If an independent variable is stochastic then it may be correlated with an error term:

$$E(X_i \epsilon_i) = X_i \cdot E(\epsilon_i) \neq 0$$

In this instance there is no hope of proving $\hat{\beta}_i$ an unbiased or consistent estimator. The test is to regress the suspected independent variable against the error term:

$$X_i = \alpha + \beta' \hat{\epsilon}_i + \epsilon'_i$$

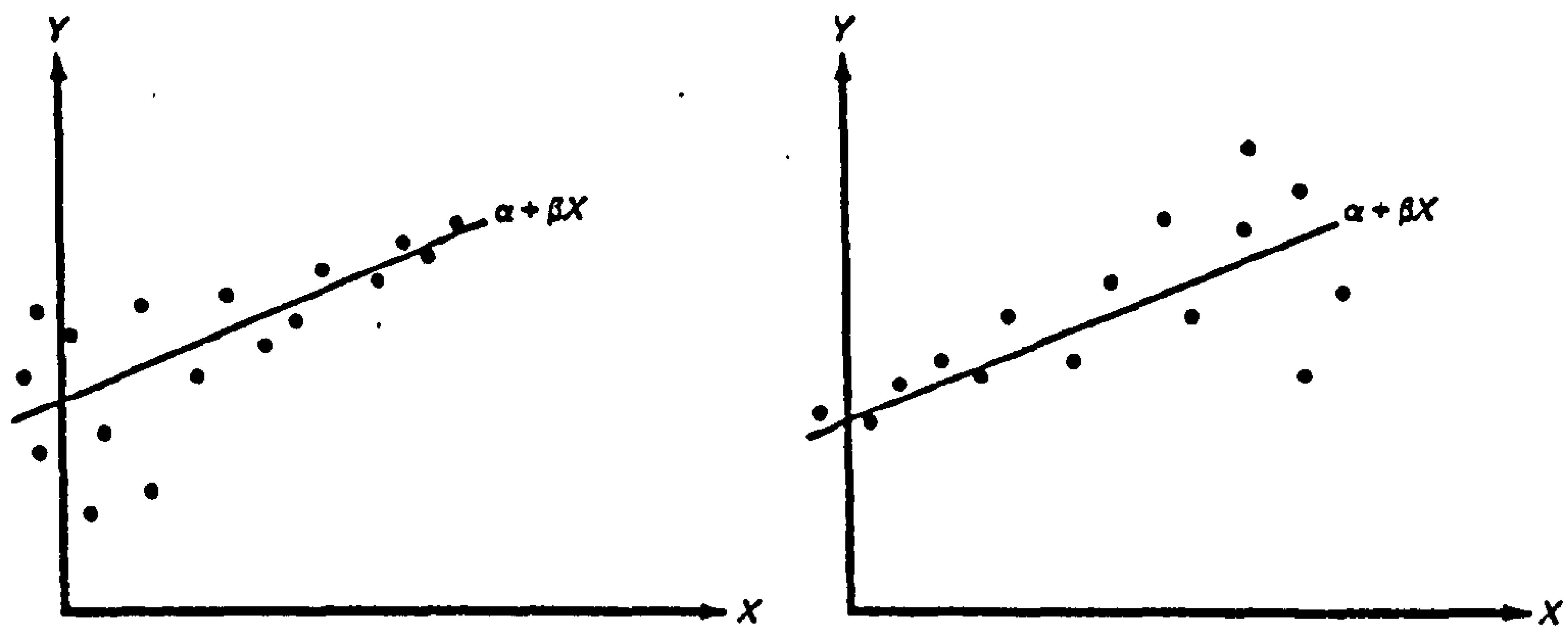
and check the correlation and *t*–statistics in hope of proving β' insignificant. If a problem is found it is normally solved by finding an instrumental variable X'_i that is both highly correlated with X_i and uncorrelated with ϵ_i.

A4.3 HETEROSCEDASTICITY occurs when

$$E(\epsilon_i^2) = \sigma_i^2 \neq \text{constant.}$$

Therefore, with the least squares residuals all weighted equally, the parameter estimator will be unbiased and consistent but not efficient. Further the estimated variances will be biased estimators of the true variance of the estimated parameters. As illustrated in Figure 13.

FIGURE A-13
Heteroscedasticity



There are several tests for Heteroscedasticity:

Bartlett's Test:

$$S = \frac{N \log_e [\sum_{g=1}^{G} (N_g/N) S_g^2] - \sum_{g=1}^{G} N_g \log_e S_g^2}{1 + [1/3 (G-1)] [\sum_{g=1}^{G} (1/N_g) - 1/N]}$$

where

$$S_g^2 = (1/N_g) \Sigma (Y_i - \bar{Y})^2$$

For each group of observations, g = 1, 2, ... G.

Having grouped the observations into G groups. Theoretically there are N! possible groups and, theoretically, all should be checked. Under the assumption of *homo*scedasticity S will be distributed as a Chi-square statistic with G−1 degrees of freedom. Clearly, this requires a computer program.

Estimates versus Residuals

By regressing the estimates, $\hat{Y}_i$, of the equation against the magnitude of its residuals, $\hat{\epsilon}_i$, and computing the correlation and t−statistic it is possible to determine if the variance varies significantly along the regression line:

$$\hat{Y}_i = \alpha + \beta' | \hat{\epsilon}_i | + \epsilon'_i$$

This method has the disadvantage that heteroscedasticity also occurs when the variance in the interior of an ordered distribution varies from the other portions of the distribution and this approach only compares a change between the extremes. Positive serial correlation of the residuals, $\hat{e}'_i$, would tend to indicate if this problem were present.Nonetheless, the method is recommended by its simplicity and because it can be applied when few observations are available.

The correction for heteroscedasticity is a procedure known as *weighted-least squares.* An ordinary least squares regression is completed and a transformation performed:

$$Y_i^* = \beta'_1 + \beta'_2 X_i{}^*_2 + \beta'_3 X_i{}^*_3 + \dots + \beta'_m X^*_{im} + \epsilon_i^*$$

where

$$\hat{\sigma}_i^2 = E(\epsilon_i^2)$$

$$Y_i^* = Y_i / \hat{\sigma}_i$$

$$X^*_{ip} = X_{ip} / \hat{\sigma}_i \qquad p = 1, 2, \dots, m$$

$$\epsilon^*_i = \epsilon_i / \hat{\sigma}_i$$

A second regression is then run for $B'_1, B'_2, \dots\dots B'_m$ which will yield a *homo-*scedastic error, indeed:

$$VAR(\epsilon_i^*) = VAR \ \frac{\epsilon_i}{\hat{\sigma}_i} = \frac{1}{\hat{\sigma}_i^2} \ VAR(\epsilon_i) = \frac{\hat{\sigma}_i^2}{\hat{\sigma}_i^2} = 1$$

The above is not strictly correct because of the use of $\hat{\sigma}_i$ rather than the true variance, σ_i, but it is rare to have the necessary *a priori* knowledge to determine σ_i. Suppose the error variances vary directly with an independent variable, X_{ip}, a procedure identical to the one above is performed except that X_{ip} replaces $\hat{\sigma}_{ip}$ and $VAR(\epsilon_i^*)$ will equal a constant rather than 1. Because in both cases the the transformed equations are *homo*scedastic, the parameter estimates will be *efficient.*

A5. TESTING THE REGRESSION EQUATION

The accuracy of fit of the equation formed by the complete set of true causal variables is important. The statistical tests assume that the model has been correctly specified and that confidence can be placed in the statistics of the independent variables.

The most common measure of goodness-of-fit can is, R^2, the square of the correlation coefficient.

Consider

$$\Sigma(Y_i - \bar{Y})^2 = \Sigma(Y_i - \hat{Y}_i)^2 + \Sigma(\hat{Y} - \bar{Y})^2 \quad \text{(See Figure 1)}$$

VARIATION IN Y	=	RESIDUAL VARIATION +	EXPLAINED VARIATION
Total Sum of Squares		Residual Sum of Squares	Regression Sum of Squares

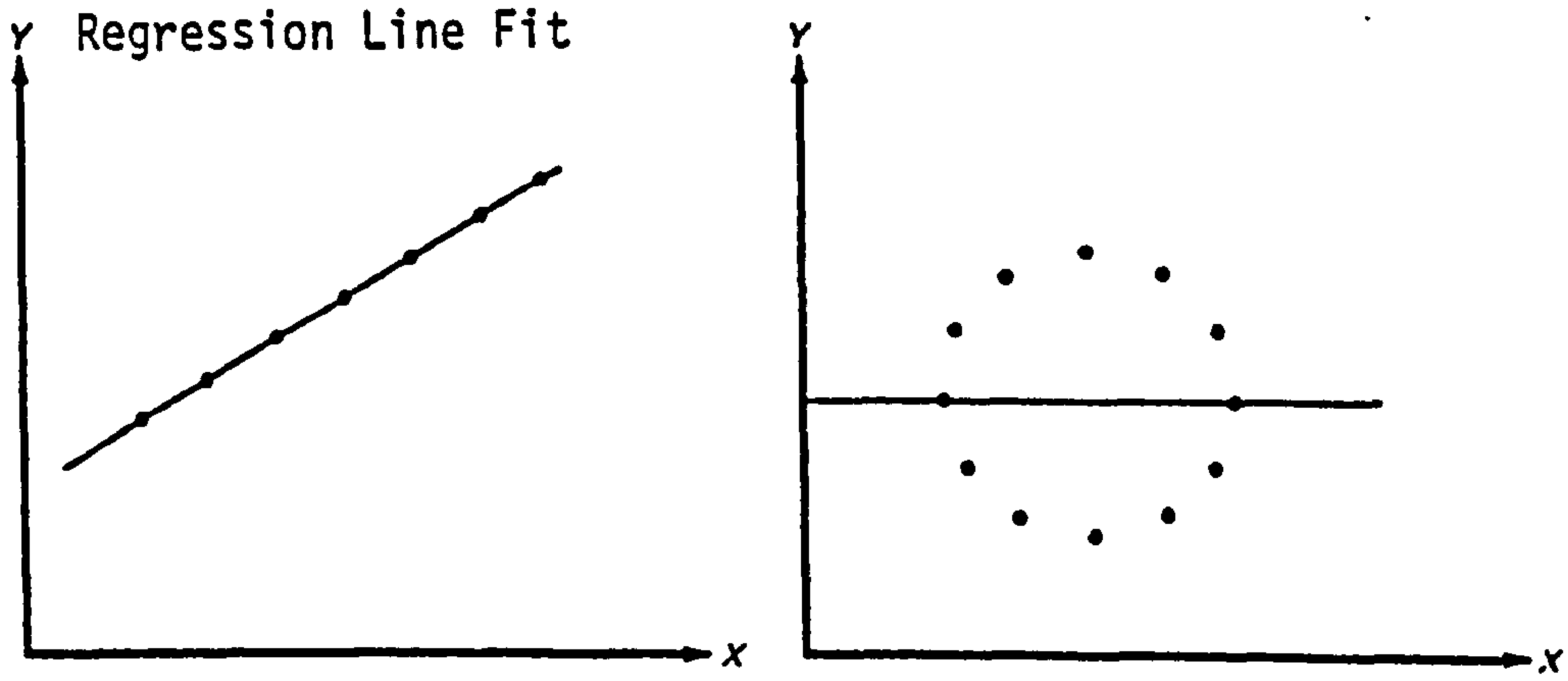
Then we can define R^2

$$R^2 = \frac{\Sigma(\hat{Y}_i - \bar{Y})^2}{\Sigma(Y_i - \bar{Y})^2} = 1 - \frac{\Sigma\, \epsilon_i^2}{\Sigma(Y_i - \bar{Y})^2}$$

Thus R^2 measures the proportion of the variation of Y_i's from their mean, $\bar{Y}$, explained by the equation, Figure 14.

FIGURE A-14

Regression Line Fit



(a) Perfect Fit (b) Regression Line Does Not Fit the Scatter of Points

There are two problems with R^2:

1. The addition of insignificant variables can never lower R^2 and may raise it. Therefore, one need only to add variables to raise R^2 without there being a requirement on their causal or other statistical significance.

2. If the model is formulated with a zero intercept, $\beta_1 = 0$, the ratio of the regression sum of squares to the total sum of squares need not lie in the range(0,1).

The corrected R^2, $\bar{R}^2$, uses variances rather than variations and thus accounts for the degrees of freedom in the problem partially eliminating the first objection to R^2.

$$\bar{R}^2 = 1 - (1 - R^2) \quad \frac{N-1}{N-M+1}$$

The same problems exist with $\bar{R}^2$ as with R^2, however, for $\bar{R}^2$ to be maximised only independent variables whose *t*–statistics are greater than one may be added.

The Chow *F*–test gives us the *F*–statistic which can be used to test the significance of R^2. The *F*–statistic with M-2 degrees of freedom in the numerator and N–M+ 1 degrees of freedom in the denominator tests whether the explanatory variables, $\beta_2, \beta_3, \ldots. \beta_m$, explain the variation of Y_i's about their mean, $\bar{Y}$:

The *F*-statistic is:

$$F_{M-2,\,N-M+1} = \frac{R^2}{1-R^2} \quad \left[\frac{N-M+1}{M-2}\right]$$

It should again be emphasised that none of the above tests ensures correct specification of the model.

A6. SPECIAL CASES

A6.1 POOLING DATA

Where Cross-Sectional parameters do not shift over time and where sufficient Cross-Sectional data are not available, it may be acceptable to pool Cross-Sectional and Time-Series data. Such a model specification suggests difficulty with the disturbance or error term which can now consist of time-series disturbances, cross-section disturbances or a combination of both. A practical resolution of these difficulties is provided by the time-series auto-correlation model which proceeds as follows:

$$Y_{it} = \alpha + \beta \quad X_{it} + \epsilon_{it}$$

where

$$\epsilon_{it} = \rho_i \, \epsilon_{i,t-1} + U_{it}$$

$t = 1, 2, \ldots, T$ Time periods

$$E(\epsilon_{it}2) = \sigma^2$$

$$E(\epsilon_{it}\, \epsilon_{jt}) = 0 \qquad i \neq j$$

$$E(\epsilon_{i,\,t-1}, U_{jt}) = 0 \quad i \neq j$$

$$U_{it} \approx N(0, \sigma_u{}^2)$$

Thus implying that cross-sectional disturbances are uncorrelated and have constant variance but time-series disturbances are auto-correlated. It is necessary to allow the auto-correlation coefficient, ρ, to vary between cross-sectional groups but account for the serial correlation within each cross-sectional group's error structure. To estimate $\hat{\rho}_i$, i = 1, 2, ... , N, an ordinary least squares regression is done over the pooled sample. Since the parameter estimates are consistent and unbiased they may be used to calculate the regression residuals, $\hat{\epsilon}_{it}$ and ρ_i may be consistently estimated as follows:

$$\hat{\rho}_i = \frac{\sum_{t=2}^{T} \hat{\epsilon}_{it}\, \hat{\epsilon}_{i,t-1}}{\sum_{t=2}^{T} \hat{\epsilon}_{i,t-1}^{2}} \qquad \text{for } i = 1, 2, \ldots, N$$

A generalised difference model of the original may now be formulated

$$Y^*_{it} = \beta X^*_{it} + U^*_{it}$$

where

$$Y^*_{it} = Y_{it} - \hat{\rho}_i Y_{i,t-1}$$

$$X^*_{it} = X_{it} - \hat{\rho}_i X_{i,t-1}$$

$$U^*_{it} = \epsilon_{it} - \hat{\rho}_i \epsilon_{i,t-1}$$

A few observations should be made at this point:

1. If N = 1 this is an acceptable generalised difference model for a pure time-series regression with serial correlation.

2. The number of degrees of freedom of the original model was $(N \cdot T) - M$ while for the generalised difference model the degrees of freedom are now $N(T-1) - M$.

3. The procedure should not be performed unless the serial correlation is *significant* because otherwise the procedure is statistically incorrect and the statistics must invariably suffer due to the reduced number of degrees of freedom.

4. The standard tests for multicollinearity, heteroscedasticity, and significance of independent variables must be applied again to the generalised difference equations. R^2, $\bar{R}^2$, t-statistics, and the F-test, may be expected to decrease due to the reduced degrees of freedom.

A6.2 DUMMY VARIABLES

Normally variables used in regression equations are assumed continuous and representative of quantitative data. In some instances, however, it may be necessary to evaluate the quantitative effect of otherwise essentially qualitative independent variables and to account for the fact that observations within a given category are associated with one set of regression parameters while observations in another category(s) are associated with a different set of parameters. Often dummy variables take on the value 0 or 1, 0 when the other independent variables are not associated with the parameter of interest and 1 when they are so associated. Two caveats are required for statistical significance:

1. The number of dummy variables to differentiate L items is (L – 1). One item must act as 'base' and it will not matter which item is chosen, the results will be the same.

2. Dummy variables decrease the degrees of freedom of the equation and must meet the same tests as other independent variables.

We may illustrate the use of a dummy variable in a two variable equation, thus:

$$Y = \beta_1 + \beta_2 X_2 + \beta_3 X_3$$

where

$$X_3 = 0 \qquad i = 1, 2, \ldots\ldots, j$$

$$X_3 = 1 \qquad i = j+1, j+2, \ldots, n$$

This may be seen to being equivalent to

$$\hat{\beta}_2 = \hat{\beta}_2 \qquad i = 1,2, \ldots, j$$

$$\hat{\beta}'_2 = (\hat{\beta}_2 + \hat{\beta}_3) \qquad i = j+1, j+2, \ldots, n$$

It is, of course, possible to change the intercept and slope concurrently.

A7. PREDICTION WITH REGRESSION EQUATIONS

The purpose of developing a regression equation is to predict future values of the dependent variable given values of the independent variables. There are two types of prediction: *Point Prediction* where only the most likely value is of interest, the forecast is generated by substituting the values of the independent variables in the regression equation and solving. *Likelihood Predictions*, on the other hand, not only give the most-likely value of the dependent variable, as above, but also the confidence interval around the most-likely value.

The parameters of the regression model are not known with certainty but instead are random variables that have been estimated, neither do we have the true error variance, σ^2, but only another estimated random variable, $\hat{\sigma}^2$, which is given by:

$$\hat{\sigma}^2 = \frac{\Sigma \hat{\epsilon}_i^2}{N-M}$$

Having estimated the regression parameters and the error variance, consider the two variable model for which a forecast Y_{n+1}, is required:

$$\hat{Y}_{n+1} = E(Y_{n+1}) = \hat{\alpha} + \beta X_{n+1}$$

Remembering that the estimated parameters, $\hat{\beta}_p$, are *unbiased* but are not identical to the true population parameters, β_p,

$$e_{n+1} = \hat{Y}_{n+1} - Y_{n+1} = (\hat{\alpha} - \alpha) + (\hat{\beta} - \beta) X_{n+1} + \epsilon_{n+1}$$

There are two sources of error in the forecast error. The first is due to the random nature of the regression parameters and is sensitive to the estimation process and hence the number of degrees of freedom involved. The second is due to the presence of the additive term, ϵ_{n+1}, and is caused by the basic variance in the variable X. The forecast variance σ_*^2, for a two variable model can be written:

$$\sigma_*^2 = \hat{\sigma}^2 \left[1 + {}^1/N + \frac{(X_{n+1} - \bar{X})^2}{\Sigma (X_i - \bar{X})^2} \right]$$

The term $^1/N$ accounts for the number of observations in the original regression and the last term

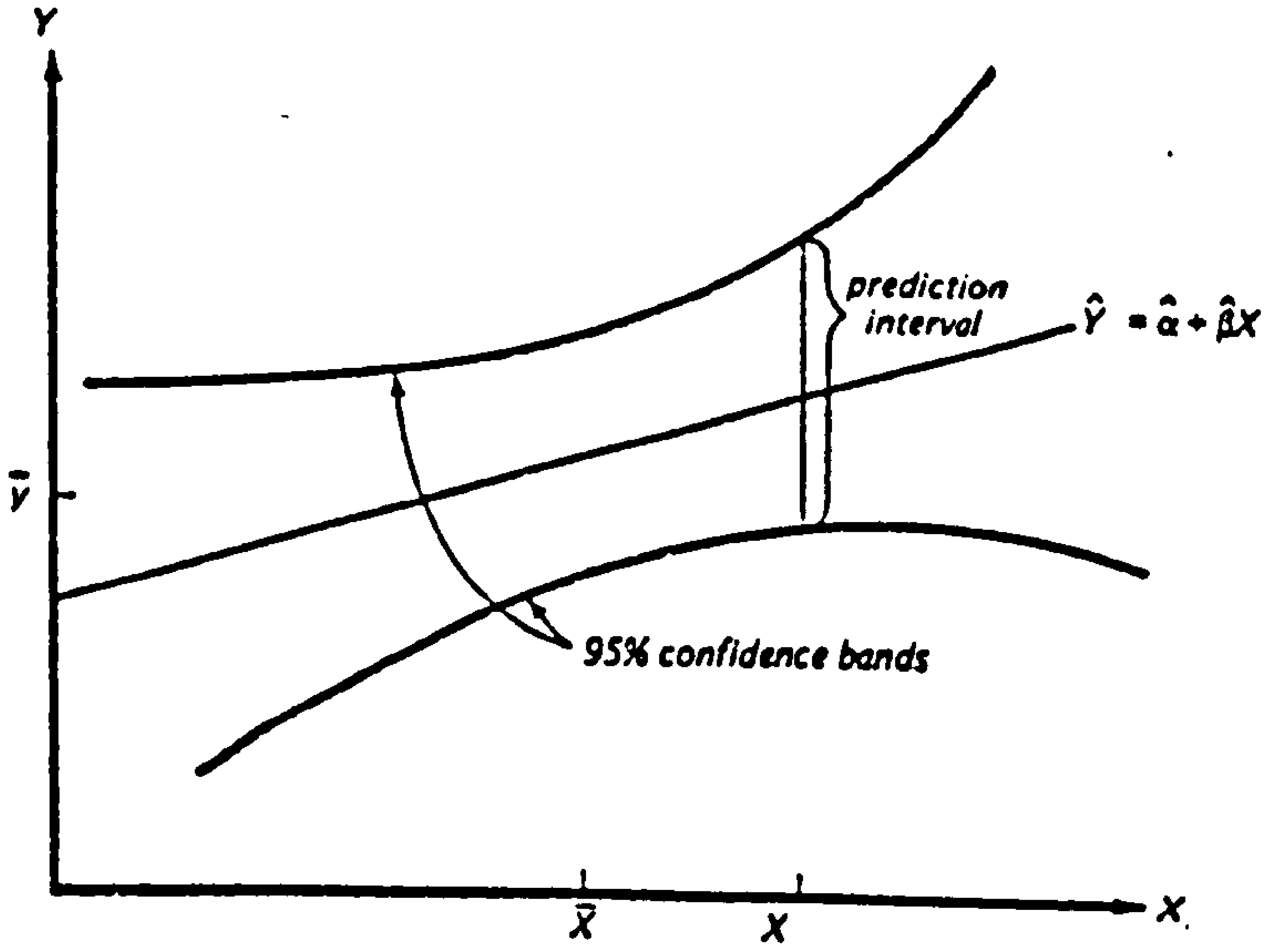
$$\frac{(X_{n+1} - \bar{X})^2}{\Sigma (X_i - \bar{X})^2}$$

accounts for the variance of X (the denominator) and the distance between $\bar{X}$ and X_{n+1} (the numerator).

The confidence interval for 95% (1.96 σ_*) is shown in Figure 15.

Note that the point of closest approach of the two *hyperbolas* is at ($\bar{X}$, $\bar{Y}$) due to the fact that the regression line is always restricted to pass through ($\bar{X}$, $\bar{Y}$), and that the hyperbolic shapes are a natural outcome of the regression coefficients being random variables. Consider the two special cases:

FIGURE A-15
Forecast confidence intervals



When the intercept, α, is known exactly and the slope, $\hat{\beta}$, is estimated.

$$\sigma_*^2 = \hat{\sigma}^2 \left[1 + \frac{X_{n+1}^2}{\Sigma(X_i - \bar{X})^2} \right]$$

and, the intercept is estimated and the slope known exactly:

$$\sigma_*^2 = \hat{\sigma}^2 \left[1 + \frac{1}{N} + \frac{\bar{X}^2}{\Sigma\,(X_i - \bar{X})^2} \right]$$

In the first case the variance of the error increases with $X^2{}_{n+1}$ while the variance in the second case is constant. This suggests that the greater $X_n + 1$ becomes the less reliable the forecast. This point becomes particularly important in time-series models because the values of $X_n + 1$ are associated with distant forecasts outside the range of experience and thus far from $\bar{X}$. *This error is not associated with any model mis-specification.*

For the multi-regression model we must use vector notation. The variance of the forecast error is given by

$$\sigma_*^2 = \sigma^2 \;[1 + \tilde{X}\,(X'X)^{-1}\,\tilde{X}']$$

where

X is a N X M matrix of independent variable observations (transformed as appropriate) and X' is its transpose

$\tilde{X}$ is a M-dimensional vector composed of the observations of the independent variable for which the variance is to be predicted and $\tilde{X}'$ is its transpose.

All the statements about the shape and variation of the confidence intervals for two-dimensional space, the two variable model, hold for M-dimensional space with M−1 independent variables. The confidence intervals will be hyperbolic and the hyperbolas will be closest at $\bar{X}_1, \bar{X}_2, \ldots, \bar{X}_m$.

Adjusting for errors in data it is necessary to consider the errors that may have been introduced into the regression equation by errors in the data base used.

σ_* may be corrected by the joint error formula to give the corrected standard error of estimate, σ_*'

$$\sigma_*' = \sigma_*(1 + \psi^2 + \phi^2)^{1/2}$$

where

ψ^2 is the square of the error in estimating the independent variable

ϕ^2 is the square of the error in the predictive power of the equation over time.

The above assumes σ_τ, ψ, and ϕ are independent. If they are not, the equation becomes:

$$\sigma_\tau' = \sigma_\tau(1 + \psi^2 + \phi^2 + 2\rho_{\sigma_\tau \psi} + 2\rho_{\sigma' \psi} + 2\rho_{\sigma' \phi})^{1/2}$$

where

ρ_{σ_τ} is the correlation between the two error components.

But they are normally considered independent. ψ and ϕ are often expressed as percentages in which case:

$$\sigma_\tau' = \sigma_\tau(1 + (\psi/100)^2 + (\phi/100)^2)^{1/2}$$

will suffice. In practice, more often than not, ψ and ϕ are unavailable and they are then assumed to be zero.

A8. ADDITIONAL INFORMATION FROM REGRESSION ANALYSIS

A8.1 ELASTICITY

The elasticity of an independent variable is defined as the percentage change in the dependent variable for a one per cent change in the independent variable. Elasticities are not necessarily constant but may change along the regression line, thus:

$$E_p = \hat{\beta}_p \frac{X_p}{Y|X_q} \quad q \neq p$$

If the model were formulated:

$$Y = \gamma_1 X^{\gamma_2} X^{\gamma_3}, \ldots, X^{\gamma_4}$$

the elasticities $\gamma_2, \gamma_3, \ldots, \gamma_m$ would be constant along the regression line.

The values are unbounded, positive or negative, and unit-free.

A8.2 BETA COEFFICIENTS

Beta coefficients are a measure of the relative importance of the independent variables in a regression model and, as such, bear a close relationship to the estimated coefficients, β_p, of the model. The Beta coefficient adjusts the estimated coefficient, β_p, by the ratio of the standard deviation of the respective independent variable thus putting all variables into the same units so that they may be compared directly. Since Beta coefficients are normalised, the constant term drops out.

$$\beta_p^* = \beta_p \frac{S_{xp}}{S_Y} \qquad p = 2, 3, \ldots, m$$

where

S_{xp} is the standard deviation of the independent variable X_p
S_Y is the standard deviation of the dependent variable Y.

APPENDIX B

SUBJECTIVE PROBABILITY DISTRIBUTIONS

B1. Introduction

This appendix explains subjective probability distributions (SPDs), and how they are developed, using the cost of crude oil as an example.

B1.1 Definition

A subjective probability distribution is a relative likelihood function that is developed subjectively by someone knowledgeable in the field because more quantitative techniques are inapplicable. Quantitative techniques may be inapplicable because of the lack of a data base, because future events are perceived as being unrelated to past events, or because they are dependent on factors different than those in the past.

In general, the procedure is to query the relative likelihood of various possibilities and, in this way, construct a relative likelihood function (SPD).

In developing SPDs, some points should be kept in mind:

1. Respondents do not always appreciate the degree of uncertainty in their knowledge of the quantities they seek to estimate and, hence, make errors in the range of possible values, and the mean value or the most-likely value (if the distribution is skewed). It is the analyst's task to judge and weight these factors accordingly.[82]

2. It is important to always assess the range first to help prevent narrow distributions.

3. SPDs by experts often have too narrow a distribution. The more expert the respondent, the more accurate the estimate of the mean, but the less accurate the estimate of the range.

4. SPDs are bound to be poorer in the tails than centrally as, by definition, tails are farther from the normal experience and expectation.

5. Hull[23] has shown that often only the mean and the standard deviation (as an indicator of the range) of a probability distribution (subjective or otherwise) are important when several probability distributions are to be combined in a model.

6. The skewness of the distribution will affect the accuracy of the estimate of the mean more than the accuracy of the estimate of the standard deviation.[23]

7. At least one technique used to develop the SPD should employ the indifference principle.[83] This occurs when the respondent

is equally indifferent to two ranges of values. He would thus be willing to place a wager on either range of values because he feels they are both equally likely even though they don't necessarily span an equal range, e.g.,

$$\int_a^b P(x)dx = \int_b^c P(x)dx \qquad [B1]$$

where

a is the bottom of the first range being considered,

b is the point of indifference,

c is the top of the second range being considered, and

P(x) is the probability function.

8. Subjective probabilities, by exposing the range, can clarify issues and eliminate alternatives.

B2. The Example

The procedure is illustrated by means of an example. The example chosen is the forecast increase in crude oil prices in the United States from 1978 to 1987. Past data exists, but it is not considered indicative of future trends. The subjective probability distribution is developed by an economist (the respondent) of a major oil company. The procedure is based on Brown, et al.[83]

B2.1 Time Period

The respondent felt there were no foreseeable discontinuities during the period (1978 to 1987) that would require the development of more than one SPD, i.e., different SPDs for different time intervals which could compose the time period.

B2.2 Range

The respondent felt that in 1978 under any scenario the minimum price could not possibly be below $8 per barrel (42 U.S. gallons per barrel). The maximum price of crude oil would be the cost of cracking U.S. oil shale into petroleum, or approximately $24 per barrel in 1978 dollars.

B2.3 The Most-Likely Value

The most-likely value in 1987 was based on 40% domestic crude at $7.82 in 1978 which is limited to a 3% per year increase in real terms by an act of Congress, and 60% foreign crude at $14.13 in 1978 that was assumed, by the respondent, to increase at half the rate of U.S. crude (1.5% per year) in real terms. The real (1978) prices in 1987 were projected to be $10.50 and $16.40 per barrel, respectively, and the most-likely price $14.04, based, again, on 40% domestic crude and 60% foreign crude.

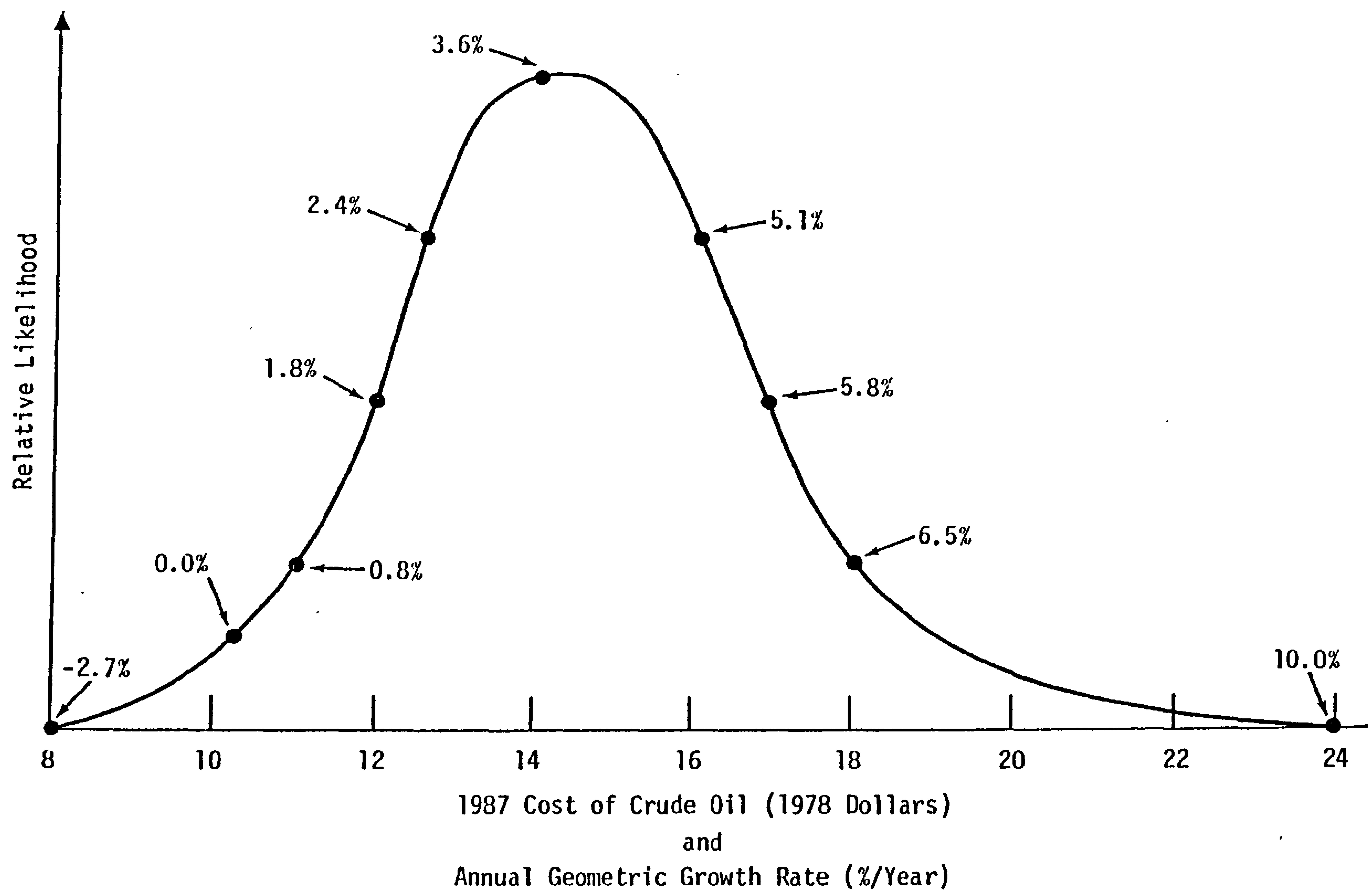


FIGURE B-1
CRUDE OIL RELATIVE LIKELIHOOD DISTRIBUTION

B2.4 Relative Likelihood

Once the range and the most-likely points were found, the point half-as-likely between each extreme and the most-likely point were estimated. On the low side this was $12 per barrel and on the high side $17 per barrel. Next, the one-quarter and three-quarters points were estimated on both sides: $11 and $18, and $13 and $16. The faired curve that results is shown in Figure B-1. The annual growth rates in percent are also given, based on 1978 dollars.

B2.5 Fractiles

Given the range, the respondent was asked what he considered the point of indifference point or fifty-fifty in 1987. (The point the respondent feels the chance of exceeding exactly equals the chance of not reaching, see equation [B1].) The estimate was fifteen dollars. The point of indifference was expected to be larger than the most-likely value, $14.04, because of the skewness of the distribution. The point of indifference between $8.00 and $15.00 was estimated next as $13.50. Then the point of indifference between $8.00 and $13.50 was estimated as $12.00. The point of indifference between $15.00 and $24.00 was estimated as $17.00, and the point of indifference between $17.00 and $24.00 was estimated as $19.00. The cumulative probability curve is shown in Figure B-2 along with the relative annual inflation values.

B2.6. Reconciliation of Curves

The frequency distribution developed by relative likelihood and shown in Figure B-1 is shown on Figure B-2 as well. The average of the two curves is used as the subjective probability distribution. (If there is reason to suspect that one curve is superior to the other a weighting system can be used.) The resulting cumulative probability curve is then converted into a frequency distribution which can be used directly with a random number generator in a risk analysis program (Figure B-3).

B2.7 Reconciliation with Respondent

After the SPD is developed it is important to give the respondent an opportunity to express "estimator's remorse." Is he happy with the range? The most-likely point? The points of indifference? The skewness of the distribution? The time periods involved? The result of this reconciliation are the curves shown.

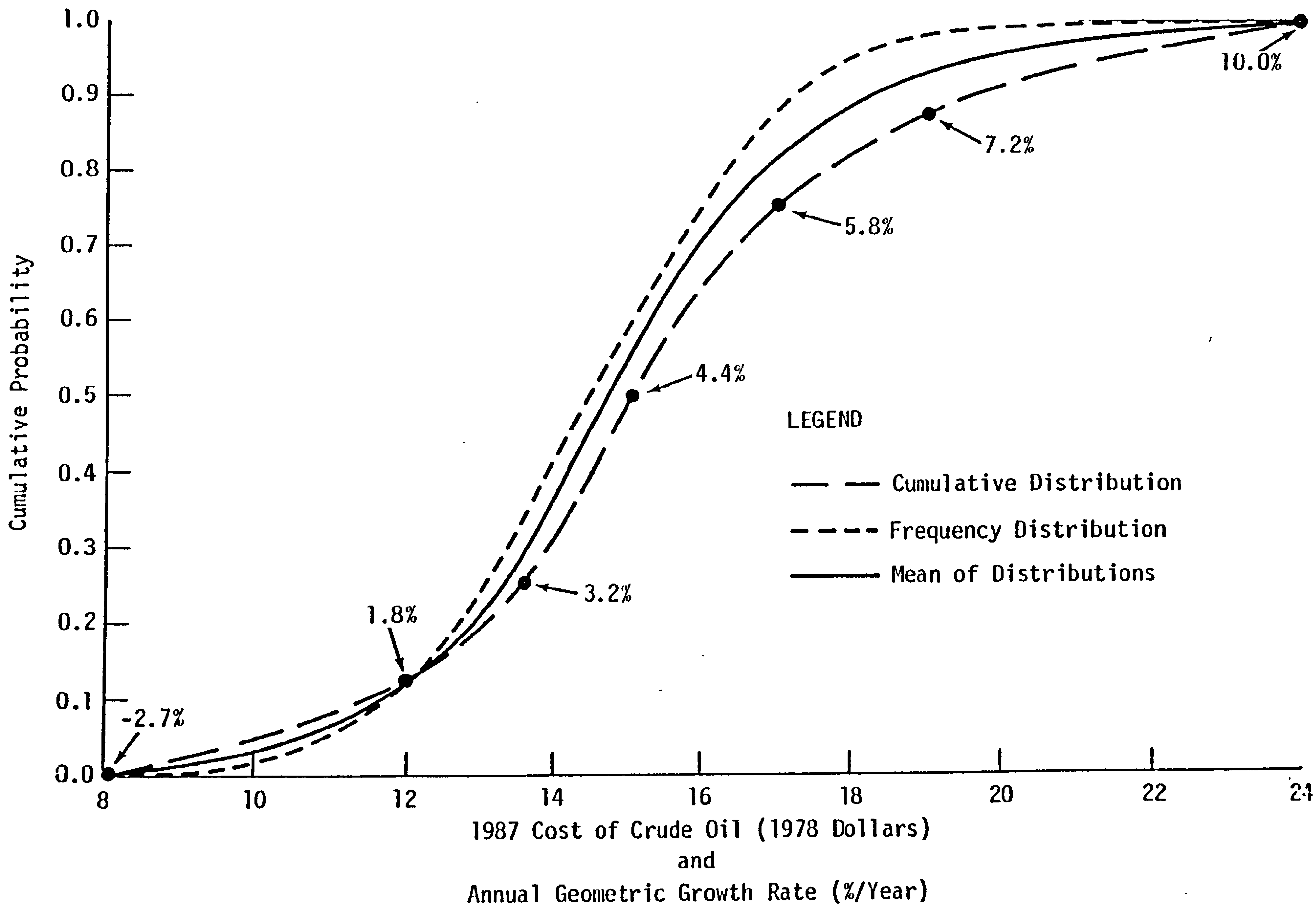
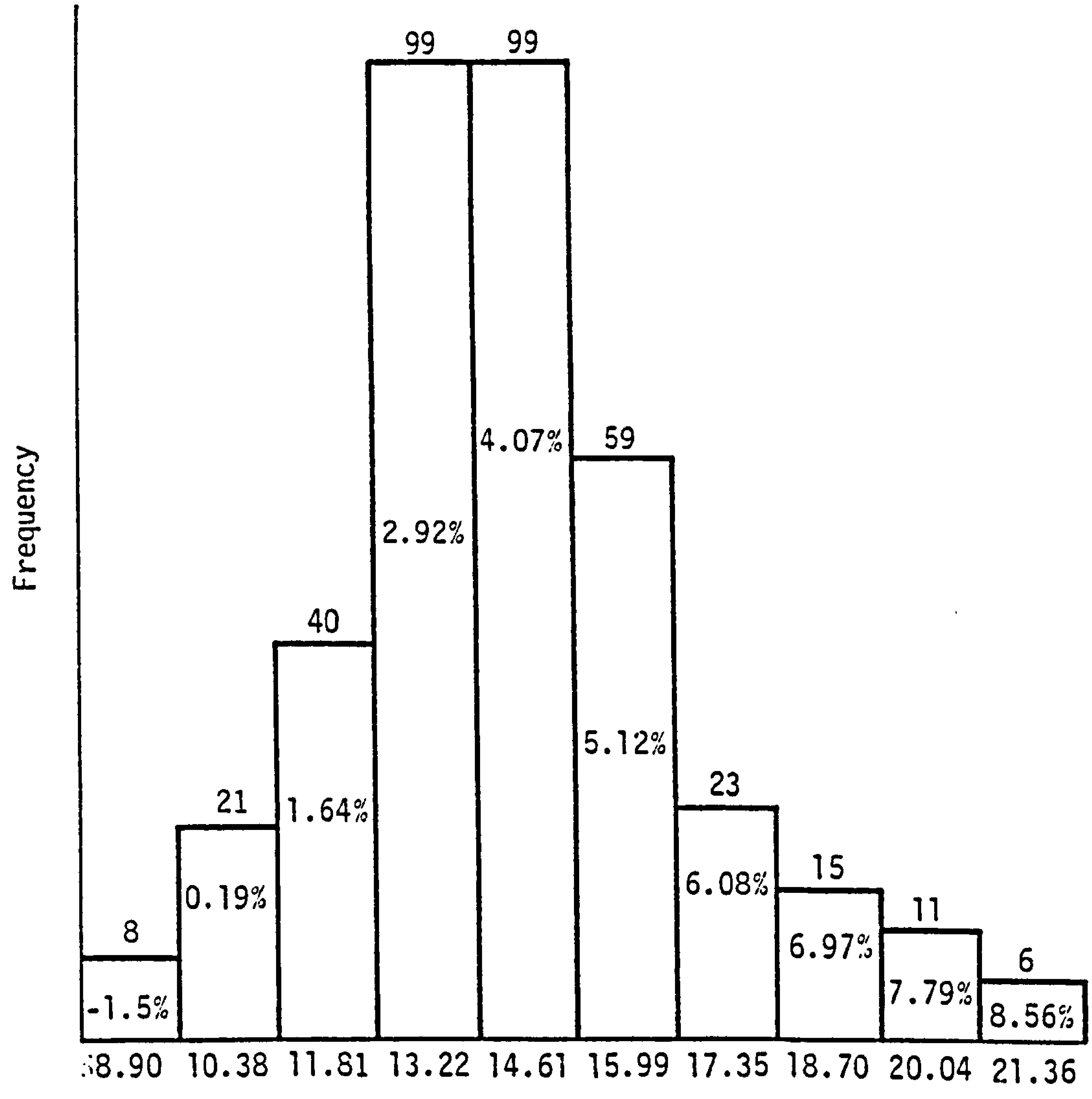


FIGURE B-2
CUMULATIVE PROBABILITY DISTRIBUTION OF 1987 CRUDE OIL PRICES



1987 Cost of Crude Oil (1978 Dollars)
and
Annual Geometric Growth Rate (%/Year)

FIGURE B-3
CRUDE OIL FREQUENCY DISTRIBUTION

APPENDIX C

WEIGHTED RANDOM WALK

C1. Introduction

Weighted random walk is used to analyze data which is not amenable to multiple regression analysis, or available from individuals in the form of subjective probability distributions. It is developed in this study to forecast price indices: inflation rate (Implicit Price Deflator for the Gross National Product (IPDGNP))[37], labor rate (Standard Industrial Classification 372)[39], and material rate (Wholesale Price Index for Industrial Commodities (WPIIC)).[41]

Inflation is determined first because the labor rate and material rate will have the effects of inflation removed.

C2. Inflation

The IPDGNP is available quarterly from 1947 through the first quarter of 1977[47], or 121 data points. No earlier data were found, even though extensive queries of the U. S. government were made.

The method is as follows

1. Each value except the first value of the IPDGNP, I_t, was divided by its previous value, such that:

$$I_t = \frac{I_t}{I_{t-1}}.$$

The resulting I_ts are an ordered set that give the IPDGNP in each period relative to the previous period. This technique is commonly used in multiple regression analysis to remove the effects of serial correlation where it is usually expressed as:

$$\log I_t = \log I_t - \log I_{t-1}.$$

2. The resulting I_ts were then checked for autocorrelation in a spectral analysis program written by the author. Unfortunately, no statistically significant correlations were found. It was suspected that there might be significant correlations, e.g., if inflation is high it will have a tendency to continue at a high rate, or, if inflation has always been relatively higher in fall and lower in spring this trend could be expected to continue. The reason such correlations did not appear may be the size of the sample, or that the data points are quarterly averages and more disaggregation is needed. If statistically significant correlations had been found a moving average model could have been developed.

3. The range of I_t was computed and divided into ten equal deciles. The I_ts were then placed in the decile whose range

included their value. Next the number of I_ts in each dectile was calculated. The mean value of each dectile and the number of I_ts in each dectile gave the frequency distribution which was the basis of the weighted random walk (Figure C-1). The term "weighted" is used because the likelihood of selecting a dectile is proportional to the number of I_ts found in the dectile; an "unweighted" random walk would have an equal likelihood of selecting from any dectile.

4. A simulation program was written using the frequency distribution and a random number generator. Each dectile was assigned an appropriate, exclusive range of values between 1 and 1000. The value generated by the random number generator thus determined the value of I_t. Forty values (quarters) of I_t were generated to cover ten years of operation of the airline model. They were combined by:

$$I_n = \prod_{t=1}^{40} I_t$$

where

I_n is the forecast change in IPDGNP over ten years.

The procedure of selecting forty I_ts and finding their product was done 10000 times. The range of I_n was computed and divided into ten equal dectiles. The I_ns were then placed in the dectile whose range included their value.

5. The tenth-root of the mean value of each dectile was found from:

$$(I_n)^{-0.1}$$

This is the mean annual inflation increment of the dectile. The likelihood of each inflation increment occuring is the number of I_ns in each dectile divided by 10000.

The resulting frequency distribution for inflation is shown in Figure C-2.

C3. Labor And Material Rates

The data for labor[39] was available monthly from 1947 through the second quarter of 1976 and material[41] was available monthly from 1908 through 1976.

The method for labor, L, and material, M, is developed as follows:

1. An average of the three months in each quarter was computed to make the data compatible with inflation.

As with inflation, the cumulative effects were removed from the data by:

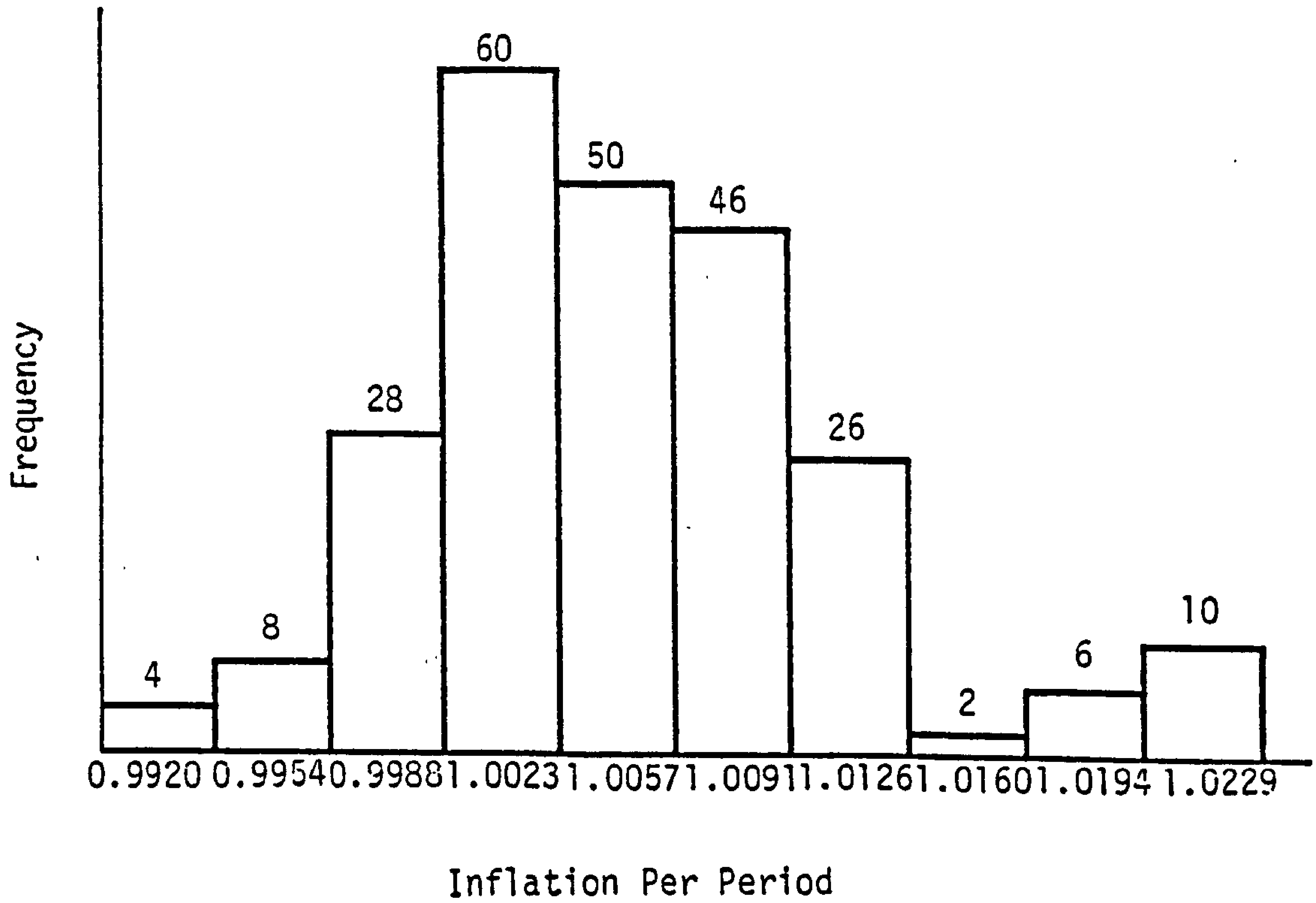


FIGURE C-1
WEIGHTED STEPS FOR INFLATION RANDOM WALK

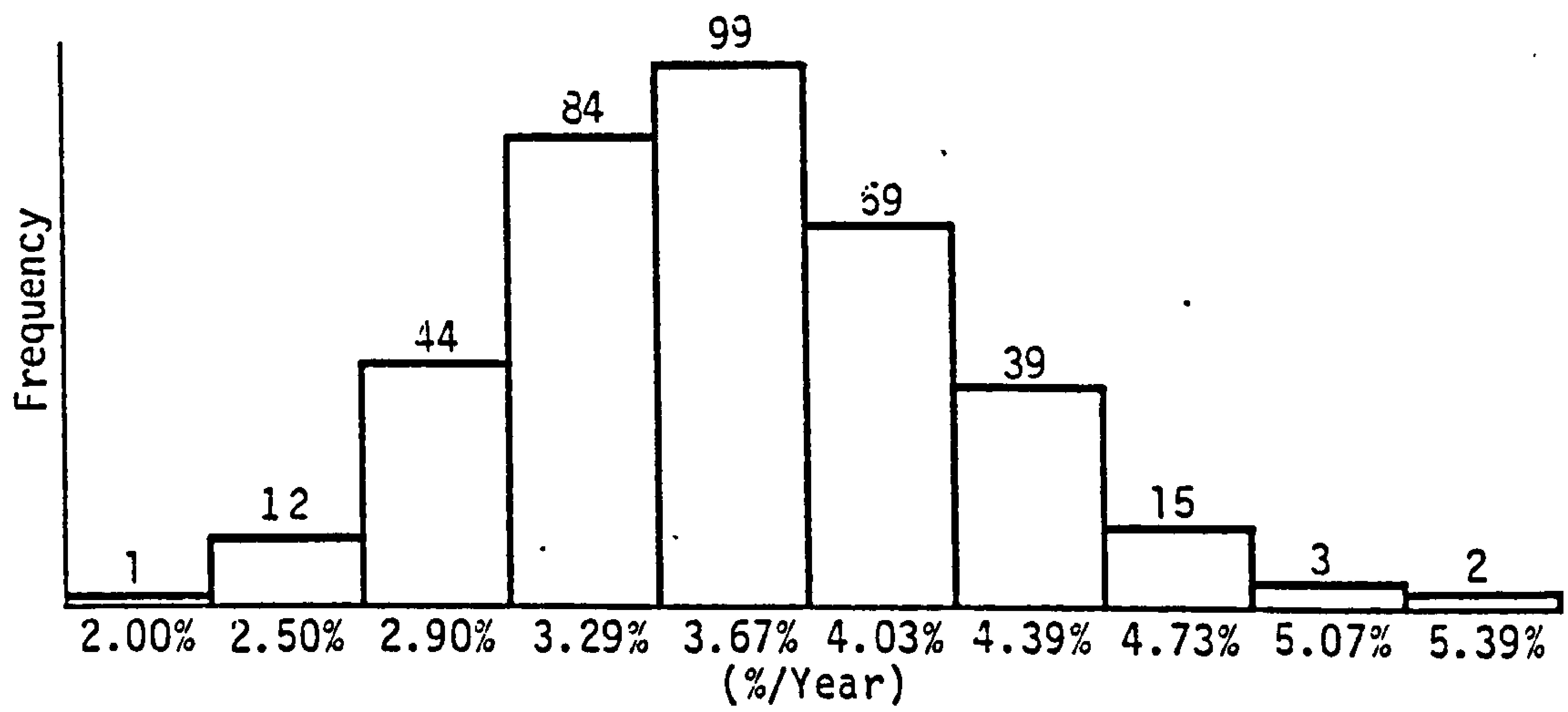


FIGURE C-2
INFLATION RATE

$$L_t' = \frac{L_t'}{L_{t-1}'}$$

$$M_t' = \frac{M_t'}{M_{t-1}'}$$

where

L_t' is the cost of labor in quarter t relative to quarter t-1 unadjusted for inflation, and

M_t' is the cost of material in quarter t relative to quarter t-1 unadjusted for inflation.

Next, the effects of inflation were removed by:

$$L_t = \frac{L_t'}{I_t}$$

$$M_t = \frac{M_t'}{I_t}$$

where

L_t is the cost of labor in quarter t relative to quarter t-1 adjusted for inflation,

M_t is the cost of material in quarter t relative to quarter t-1 adjusted for inflation, and

I_t is the IPDGNP in quarter t relative to quarter t-1.

2. This is the same as step 2. for inflation. Again, no significant autocorrelations were found. However, when the data for the material (WPIIC) was run monthly from year 1908, before removing the effects of inflation, significant autocorrelation was found. The autocorrelation occurred at thirteen months, t-13, because there is no rational explanation, e.g., seasonal fluctuations, annual fluctuations, political elections, it is doubtful the relationship is causal.

3. Same as inflation. See Figure C-3 and C-4.

4. Same as inflation.

5. Same as inflation. See Figure C-5 and C-6.

Steps 3-5 were done again for a one year time period (four quarters). The mean value (growth) was then removed to get a normalized distribution that was used in the cost simulation program to get the probable distribution of costs during the start-up year.

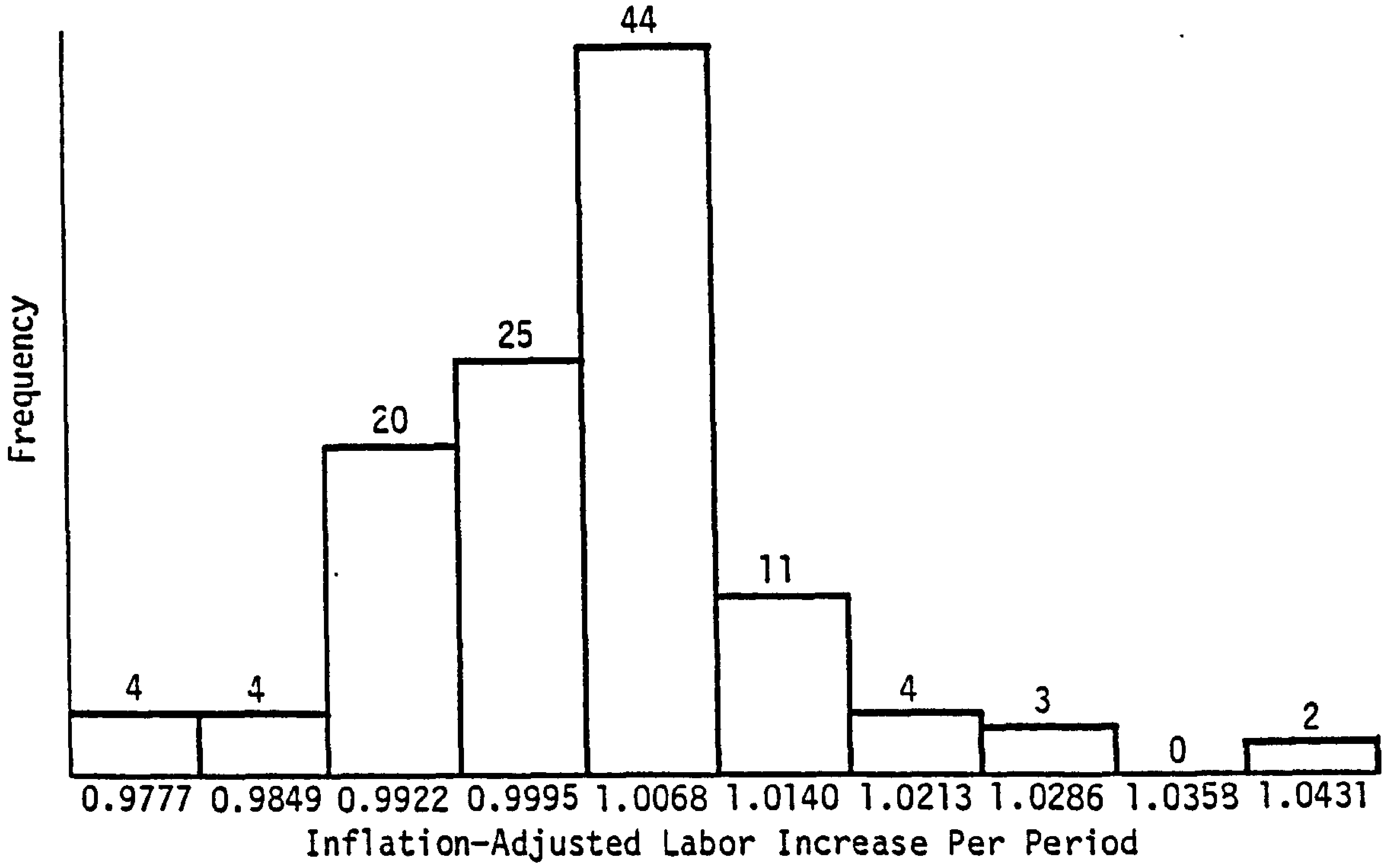


FIGURE C-3
WEIGHTED STEPS FOR LABOR RANDOM WALK (SIC 372)

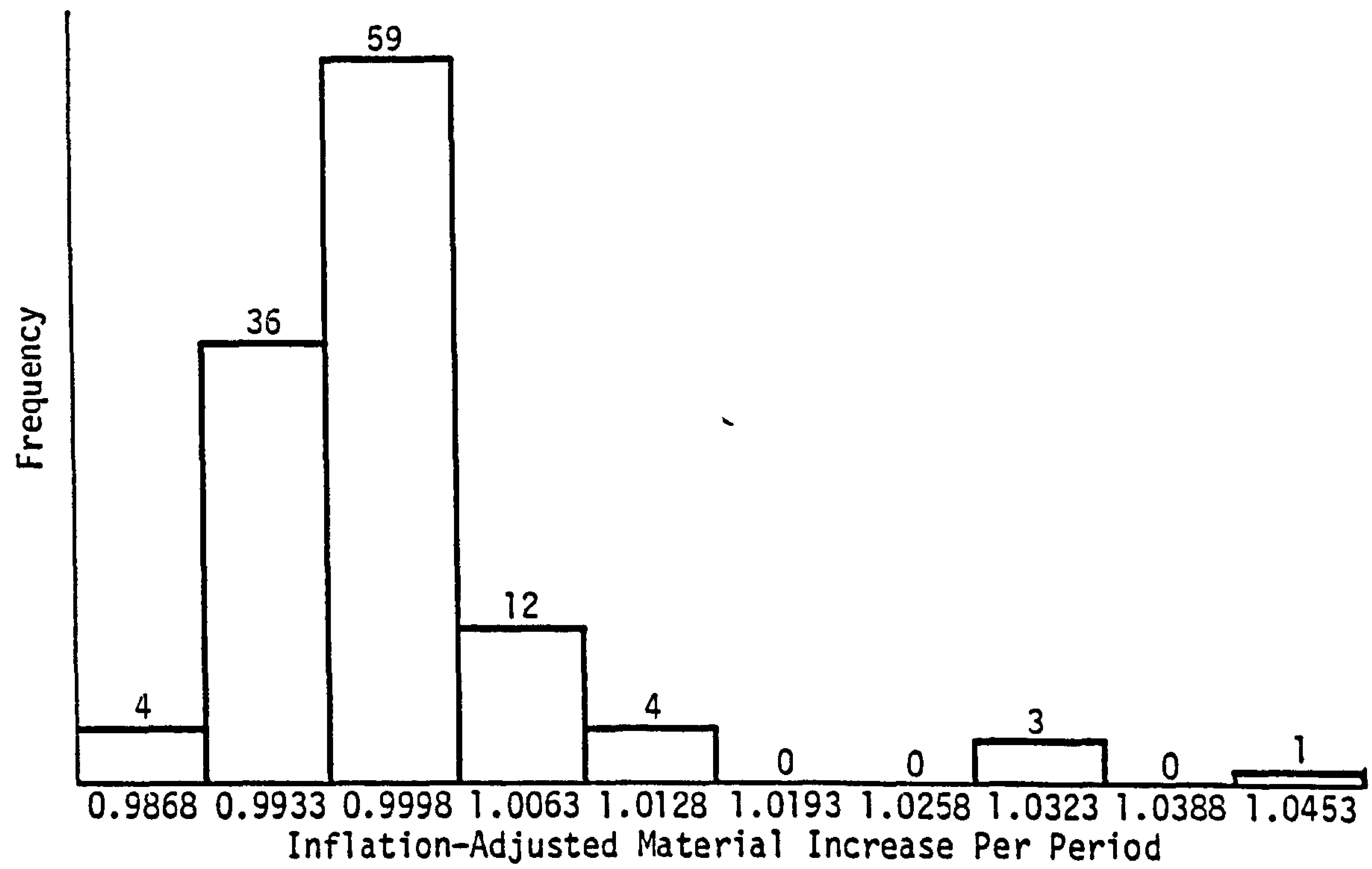


FIGURE C-4
WEIGHTED STEPS FOR MATERIAL RANDOM WALK (WPIIC)

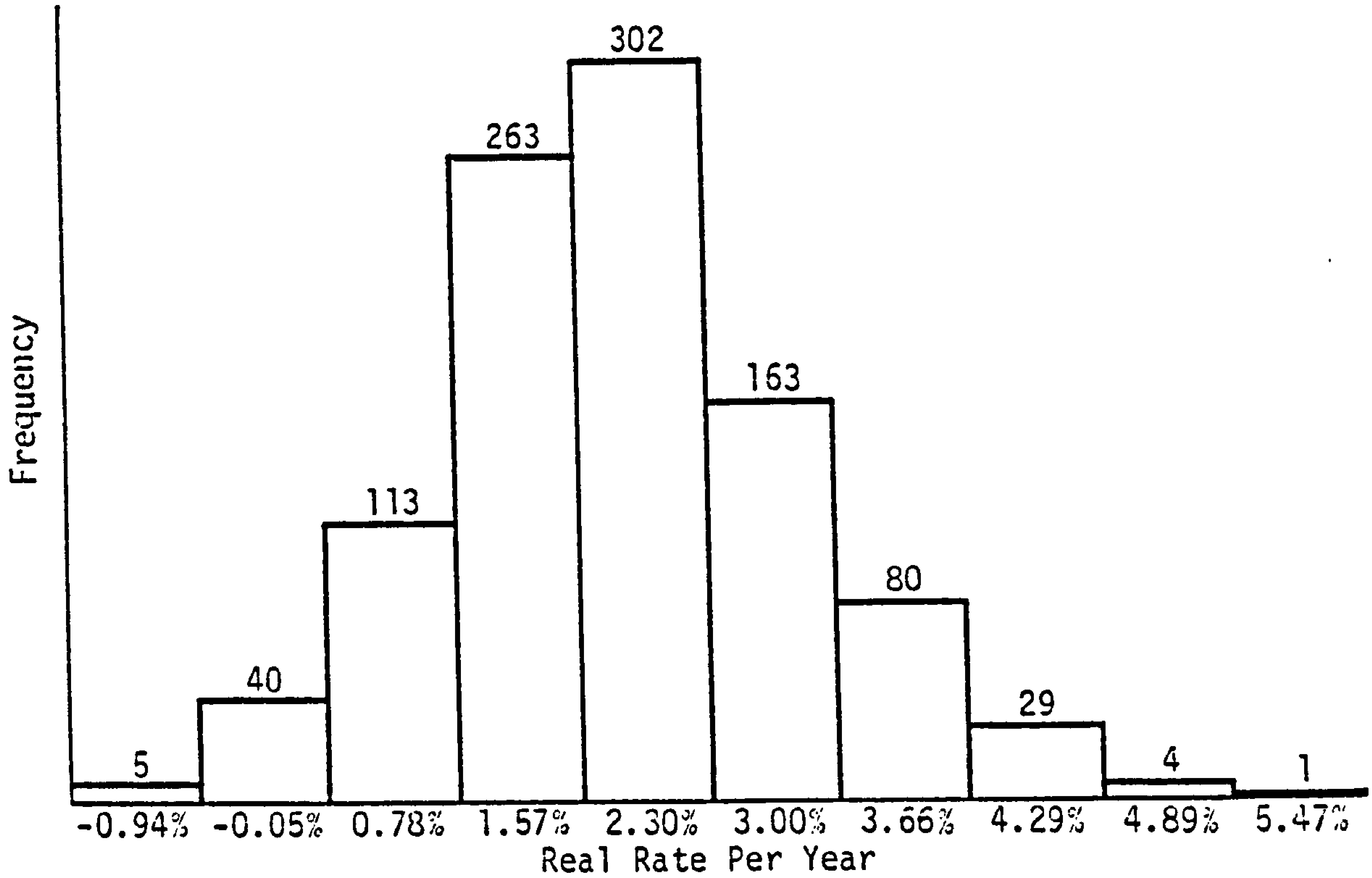


FIGURE C-5
LABOR RATE FREQUENCY DISTRIBUTION

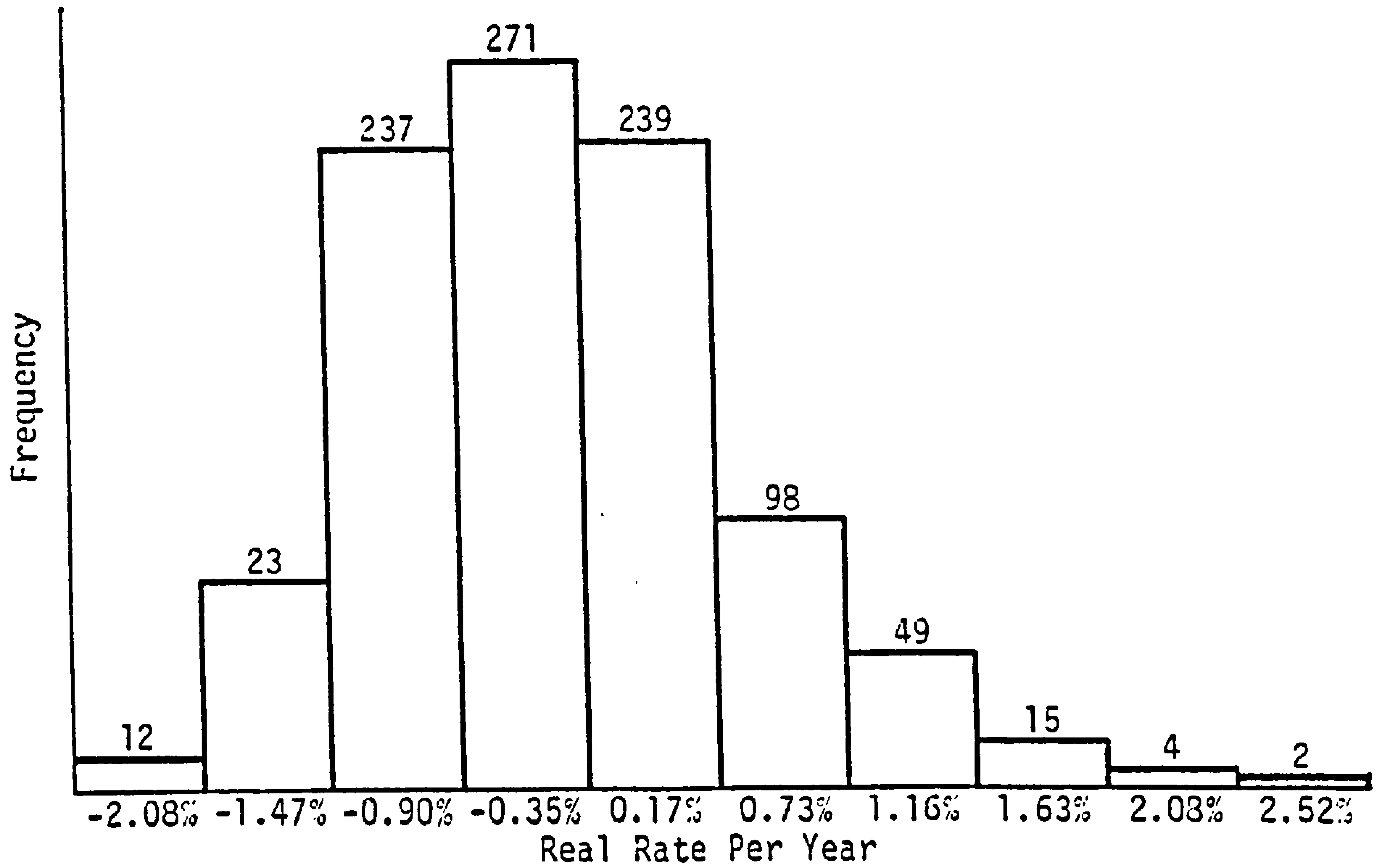


FIGURE C-6
MATERIAL RATE FREQUENCY DISTRIBUTION

TABLE D-1

DAILY SCHEDULED COMPETITION: THIRD-LEVEL VS THIRD-LEVEL[6]
(New England States, 1967-1972)

Daily Passenger Volume	Competitive Opportunities	Instances of Competitive Service	Frequency of Competition (%)
Over 50 passengers	132	23	17.4
25-50 passengers	110	11	10.0
Under 25 passengers	231	5	2.1
Totals	473	39	8.2

APPENDIX E

ASSISTANCE AVAILABLE TO THIRD-LEVEL AIRLINES

This appendix consists of five tables outlining assistance available to third-level airlines. The assistance may be in the form of direct aid, cooperative agreements, self-help or commissions. The contents is Governmental Assistance Options, Table E-1; Organizations, Table E-2; Certificated Carrier Assistance, Table E-3; Airline Self-Help, Table E-4; and Commissions to Travel Agents, Table E-5.

APPENDIX D

DESTRUCTIVE COMPETITION AMONG THIRD-LEVEL AIRLINES

Often when one airline is faced with competition from another and it sees the possibility of regulatory relief, it raises the spectre of "destructive competition." The implication being that, if competition is allowed, both airlines will fail and service will terminate. It is sometimes used by third-level airlines operating pursuant to a state public utilities certificate or a state charter, when they see new competition.

The prerequisites for destructive competition are high fixed-costs (relative to total costs), immobility of the industry (resulting in excess capacity under both short-term and long-term demand fluctuations), competitors too numerous to act for the collective good, and economies of scale.[6]

In a survey of eight third-level carriers the ratio of fixed to total costs ranged from 13-37% with an average of 24.2%. This compares favorably with the 30% fixed costs experienced by trunk airlines on strike. Regarding immobility, about the only things an airline couldn't move anywhere and have operational in 60 days are its buildings, and these can be rented. The nature of the industry is mobility: aircraft are nationally mobile, and labor and management are regionally, if not nationally, mobile. Generally, the established airline is only complaining about one or two competitors, but never several. Third-level airlines do not exhibit many economies of scale. (This is discussed further under Airline Costs, Section 3.) Mallet[6] finds that, over time, the concentration of traffic once found in the top carriers is being more equitably distributed as carriers tend to specialize in certain markets. This indicates possible diseconomies of scale. In fact, third-level airlines rarely compete where there is insufficient traffic for two carriers (Table D-1).

All this is not to say that the ousting of a less efficient firm by a more efficient firm is not destructive from the viewpoint of the less efficient firm. However, this is only healthy free enterprise not destructive competition in the economic sense.

TABLE E-1

GOVERNMENTAL ASSISTANCE OPTIONS

Category	Federal	State	Local
Regulatory	Third-Level Certification	Route Protection	Favored Carrier Restrictions
	Route Protection	Intrastate Limitation on Inadequate Certified Service	
Direct Financial	Contract Services	Seat Guarantees	Seat Guarantees
	Direct Subsidies	Multi-Modal Packages	Revenue Sharing
	Flow-Through Subsidies	Cross-Subsidies	Treat Nontenants as Tenants
	Guaranteed Loans	Assistance Payments to Communities	Assistance Payments to Operator
	Mail Contracts		Emergency & Medical Contracts
	Federal Assistance Grants	Transportation Coupons	Lease A/C to Operators
	Buy Nonvoting Airline Stock	Lease A/C to Operator	Buy Nonvoting Airline Stock
		Buy Nonvoting Airline Stock	

TABLE E-1
(concl'd)

GOVERNMENTAL ASSISTANCE OPTIONS

Category	Federal	State	Local
Airport & Service	Airport Class Redesignation	Airport Improvements	Improved Facilities & Equipment
			Improved Airport Access & Parking
	Airport Improvements (ADAP)		Promotional Assistance
	Facilities & Equipment (F&E)		Free Facilities & Services
Taxation	Increased Tax Credits	Sales Tax Relief	Property Tax Relief
	Ticket Taxes on % of Revenue rather than Head Tax.	Ticket Taxes on % of Revenue rather than Head Tax.	

TABLE E-2

ORGANIZATIONS

Air Traffic Conference of America (ATC)

Interline Ticketing and Baggage Agreement
Standard Interline Passenger Procedures Manual (SIPP)
Interline Freight and Small Package Service Agreement

International Air Traffic Association (IATA)

Interline Agreements Passengers and Cargo (Approximately $3000 annually)

Airline Clearing House (ACH)

($100 deposit plus approximately $200 annually)

Standard Agent's Ticket and Area Settlement Plan

(Approximately $2000 dues and $4000 fees annually)

Scheduled Airline Traffic Offices (SATO) - Military & NASA Bases

Universal Air Travel Plan (UATP)

($425 deposit)

Air Cargo inc. (ACI)

Air/Truck Interline Agreement ($500 annually)

Aeronautical Radio, Inc. (ARINC) services

Air/Ground Domestic (AIG DOM)
Electronic Switching System (ESS)
Supplemental Services (SUPPSVCS)
Private Line Intercity Network (PLIN)
Local Area VHF Air-Ground-Air Radio Communications Service

Commuter Airline Association of America

Workshops on regulations, financing, and shared computer reservation systems
Cargo training with United Air Lines
Uniform system of accounts
Publishes "Times", "Labor Newsletter", and "Commuter Airline Industry", an annual report.

TABLE E-2
(concl'd)

ORGANIZATIONS

Publishers

Ruben H. Donnelly Corporation

Official Airline Guide (OAG)

Air Cargo, Inc. (ACI)

Air/Truck Directory (approximately $500 annually)
Air Freight Directory

Airline Tariff Publishers (ATP)

Squires Tariffs (Passenger)
Air Cargo Guide
Commuter Airline Local Cargo Rules & Rates Tariff

Large Users

Group rates
Block tickets
Cargo contracts
Special services (emergency and medical contracts, etc.)

Airport Planning Committees

Get representation

Fixed-Base Operators (FBOs)

First service contracts
Charter back up
Favorable rates

Chamber of Commerce

Put joint flyers & timetables in mailings
Provide industrial leaders & travel arrangers with information
Make announcements to members

TABLE E-3

CERTIFICATED CARRIER ASSISTANCE

Joint fares on basis of DPFI for passengers, baggage, and freight

Cooperate on interline connecting schedules

Joint newspaper, television, radio, billboard, and terminal advertising

Joint sales calls on commerical accounts and travel agencies

Joint meetings with Chambers of Commerce

Interline agreements for passengers, baggage, and air freight

Joint development of interline promotional materials

Interline schedules in each airline's schedule

Provide meals, lodging, and alternative transport on interrupted trips

Provide traffic and aircraft handling at major terminals

Provide reservation system, telephones, and notification of change to passengers

Pay third-level operator as travel agent and vice versa

Fight the "scope clause"

Support third-level carrier's need for the same terms from airport & vendors

Sell each other's tickets on a space-available basis

Enter into suspension/replacement agreements at appropriate stations

Absorb all proration on joint fares

Use third-level carrier's charter facilities

Joint group rates and block sales agreements

Favor third-level operator as supplier where appropriate

Freight ground handling agreements--loading and unloading (easiest agreement) terminal handling, clerical support (most difficult agreement)

TABLE E-4

AIRLINE SELF-HELP

Most comfortable and profitable aircraft

Special services for handicapped or disabled travelers (canes, crutches, folding wheelchairs, guide dogs, braille emergency cards)

Special preparation for the needs of children in flight

Special services for the carriage of pets

Baggage handling and speedy return at airline's expense in the event of mishandling

Payments to passengers in event of overbooking or luggage damage

One-call service including air travel, car rental, and hotel reservations.

In-flight stereo and drinks

Special services in the event of misconnections or flight delays

Special credit arrangements for purchasing air travel (airlines pioneered the air travel card)

Tour and charter services

TABLE E-5

COMMISSIONS TO TRAVEL AGENTS

Scheduled Services:	
- Domestic travel at agency "in-plant" location	3%
- Domestic transportation	7%
- International transportation	7%
- Family plan tariff used	8%
- Family travel involved	8%
- Approved excursion fare	8%
- Incentive air tour	10%
- International tour	10%
- Convention air tour	10%
- Independent air tour	11%
- Advertised air tour	11%
Charter Service:	
- On actual transportation mileage charges only	5%

APPENDIX F

PROFILE OF A MODEL THIRD-LEVEL AIR CARRIER[54]

F1. Management

a. Control of overall operations by one individual having a minimum of five years prior experience managing air taxis or airlines.

b. Formal organizational arrangement with written delegation of authority and responsiblity for each phase of the operation.

c. Experienced department heads, e.g., flight, stations, maintenance.

d. Good employee morale and low turnover of key personnel, e.g., chief pilots, department heads, and operating officers.

e. Individual or committee overseeing safety and reporting to senior executive.

f. Reputation as safety-minded; cooperative with federal regulatory agencies.

g. Formal system of record keeping for all operations, e.g., passenger and cargo manifests.

h. Satisfactory relationships with employee unions.

F2. Financial Position

a. Sound, nonspeculative ownership.

b. Satisfactory financial rating; not overdue in accounts payable, adequate cash balance for present and foreseeable needs.

c. Making a profit or evidence of planned improvement from expected initial deficit.

F3. Routes

a. No unusual physical hazards (terrain, weather).

b. No abnormal competition.

c. Realistic program for expansion (market analysis as basis for current and future activity).

d. Adequate airport facilities and en route nav-com aids.

APPENDIX F
(cont'd)

PROFILE OF A MODEL THIRD-LEVEL AIR CARRIER

F4. Loss Record

a. Prior three year insurance loss ratio of 30% or less, excepting a single catastrophe.

b. No unusual frequency or repetition of losses of similar type.

F5. Aircraft

a. Well-maintained multi-engine aircraft meeting all FAA requirements and adequately equipped for use and flying conditions.

b. Homogeneous fleet with average age under five years.

c. Fleet is tied down, if not hangared.

F6. Operations

a. General

1) Operations manual, current and widely distributed, covering each phase of flight and ground activity.

2) Strict enforcement of all FARs, especially Parts 121 or 135, as appropriate.

3) Designation of chief pilot for flight operations and chief station agent for ground station activity.

4) Centralized reporting of all accidents, injuries, and irregularities.

5) Pilots

a) No part-time pilots.

b) Verification of record of previous employment and flight experience.

c) Records kept of date of medical examinations and flight checks of each pilot.

d) Program for regular flight checks (FAA and route).

e) Completion of manufacturer's school, or authorized substitute, for turboprop or jet aircraft.

APPENDIX F
(cont'd)

PROFILE OF A MODEL THIRD-LEVEL AIR CARRIER

f) Program for initial training and recurrent training (training manual).

g) Flight crew with experience, in flight hours, equivalent to

i. Captain--Airline Transport Pilot License; Pilot-In-Command Time (hours): 3000 Total Time, 1000 Multi-Engine, 500 Similar Make & Model, or 100 Specific Make & Model.

ii. Copilot--Commercial and Instrument License Pilot-In-Command Time (hours): 1500 Total Time, 500 Multi-Engine, 100 Similar Make & Model, or 25 Specific Make & Model.

h) Minimum crew interchange between different models of aircraft.

6) Station and flight attendants.

a) Formal program for initial training and recurrent training.

b) Safety oriented.

7) Incidental mail or cargo hauling to the same standards as passenger carrying.

8) Food or beverage service

a) Adequate and sanitary facilities for food preparation and storage.

b) Standardized methods of serving.

b. Flight

1) Schedules and initial "go/no go" decision by certificated dispatcher.

2) Supervised by chief pilot.

3) Comprehensive emergency procedures ensuring passenger safety.

4) Minimum equipment list.

APPENDIX F
(cont'd)

PROFILE OF A MODEL THIRD-LEVEL AIR CARRIER

5) Well-defined crew duties.

6) Adequate facilities and procedures for preflight, weather briefings, and checklist use.

c. Ground Stations

1) Procedures for remaining overnight and obtaining turnaround service for aircraft.

2) Sufficient terminal and ramp space to minimize congestion.

3) Direct control of passenger boarding and deplaning by company employee.

4) System for baggage handling.

5) Safe and well maintained public areas.

6) Constant supervision by chief station agent.

F7. Servicing, Repair, and Inspection

a. General

1) Manager in overall control of servicing and repair.

2) Work areas are clean, safe, and organized.

3) Standard operating procedures (maintenance manual) for each type of activity.

4) Adequate tools and equipment that are well maintained.

5) Formal system for crew "squawks" and follow up.

b. Servicing

1) Taxiing of aircraft by designated, qualified employees only.

2) Fueling procedures, equipment, and bulk storage inspected and performed by qualified personnel.

c. Repair

1) Controlled by designated chief mechanic with full authority.

APPENDIX F
(cont'd)

PROFILE OF A MODEL THIRD-LEVEL AIR CARRIER

2) All mechanics experienced in aircraft being maintained with attendance at factory schools or equivalent for sophisticated aircraft, e.g., turboprops and jets.

3) Lead mechanics with Airframe and Powerplant (A&P) and Inspection Authorization (IA) ratings.

4) Manuals, texts, Airworthiness Directives (ADs) and factory bulletins up to date for all aircraft.

5) Comprehensive records of work performed.

6) Procedures for servicing or repair away from home base.

7) Comprehensive maintenance manual; kept current.

8) Experienced and reputable outside repair facilities.

d. Inspections

1) Chief inspector with IA reporting to operating officer other than maintenance head.

2) Permanent record of inspections performed.

F8. Airports

a. General

1) Uses only airports in regular and continuous use by general aviation or certificated carriers.

2) Adequate navigation and communication facilities.

3) Regulated ground and flight movement as per posted directives.

4) Free-swing wind tee or wind sock.

5) Air approaches clear, unobstructed, and marked.

6) Adequate fire and rescue protection available.

7) Adequate snow removal.

APPENDIX F
(concl'd)

PROFILE OF A MODEL THIRD-LEVEL AIR CARRIER

8) Daily inspection of area; appropriate maintenance.

9) Protection of aircraft from theft or vandalism.

10) Protection of customers, general public, and property from injury or damage.

b. Hangars and Buildings

1) Resistant to collapse from snow or wind.

2) Approved heating plant and electrical installation.

3) Lighting giving true color depiction.

4) Evidence of good housekeeping.

5) If there is multiple occupancy or use of an area, there must be adequate separation.

6) Ease of emergency movement of aircraft, personnel, and passengers.

c. Tie Downs

1) Sufficient in number

2) Proper construction

d. Ramps, Aprons, Taxiways, and Runways

1) Surface free of obstructions, adequate in strength, properly pitched, drained, and marked.

2) Width sufficient to prevent interference with adjacent objects including shoulders.

3) No interference from auto roads or traffic.

e. Ground Vehicles

1) Properly maintained and in safe operating condition, e.g., brakes and lights.

2) Trained drivers.

APPENDIX G

MAINTENANCE CONCEPTS

G1. Types Of Maintenance

There are two basic types of maintenance:

1. Scheduled Maintenance--This is the systematic testing, replacement, adjustment, and cleaning of components and systems.

2. Unscheduled Maintenance--This is generated by observed defects during turnarounds, scheduled maintenance, and bulletins from the government and manufacturers.

It is fair to say that scheduled maintenance always costs less, or, at least, never costs more than unscheduled maintenance for the same job. The objective, then, is to handle as much maintenance as possible as scheduled maintenance.

G2. Functions of the Maintenance Organization

To cope with the two types of maintenance, a tri-functional organization is set up. Sometimes the functions are very distinct and at other times, such as when one man comprises the maintenance organization, they are indistinguishable. The functions are production planning and control, maintenance, and quality control.

G2.1 Production Planning and Control

The objectives of production planning and control are to accomplish the following:

1. Ensure on-time delivery of serviceable aircraft for flight.

2. Minimize aircraft downtime for attainment of high utilization.

3. Minimize labor costs for maintenance purposes.

4. Balance investment in plant and inventory against specified performance levels.

5. Optimize utilization and productivity of manpower.

G2.2 Maintenance

The objectives of maintenance are to accomplish the following:

1. Prevent deterioration in the inherent design levels of safety and reliability.

2. Improve the design levels of safety and reliability.

3. Obtain, maintain and dispose of equipment in such a manner as to minimize per unit costs. In this instance, the unit is the available seat mile.

G2.3 Quality Control

The objectives of quality control are to accomplish the following:

1. Ensure compliance with statutory and airline safety requirements.

2. Development of component lives to keep floats and labor force at a highly economic level.

G3. Maintenance Systems[43]

There are three maintenance systems in common use: the pyramidal system, the progressive or equalized system, and the calendar system.

G3.1 Pyramidal System

The pyramidal system does a basic set of jobs at fixed intervals. Each set is added at a multiple of the basic interval. The system gives a small number of large checks which are easy and economical to perform because:

1. Preparation and completion phases are kept to a minimum.

2. Large checks allow good manpower utilization.

3. Jobs have a fixed content which reduces the planning and control requirement.

G3.2 Progressive or Equalized System

The progressive or equalized maintenance system attempts to spread the work out. The aircraft is maintained over many more maintenance intervals per unit of flight time. Not only is there less maintenance done per check, but it is often less well-defined (partial checks, etc.). The maintenance can often be fully completed in nonoperating periods using this approach.

There are three stages of equalization:

1. Minor checks are equalized.

2. Major checks are spread over the minor checks.

3. Specific work is then put into small packages of from two hours to overnight in length.

G3.3 Calendar System[84]

Aircraft are overhauled on the basis of calendar time. This provides tail-number-by-tail-number planning, but necessitates that, overall, aircraft be overhauled more frequently to ensure that a sufficiently low percentage (≤15%) of aircraft exceed the more traditional limits of flight time or flight cycles. The system results in:

1. Increased ability to plan.

2. Stabilized work force.

3. Reduced benefit from cycle-limited parts.

G4. Maintenance Philosophies

The two main maintenance philosophies are hard-life and on-condition.

G4.1 Hard-Life Philosophy

The historical approach to maintenance is the hard-life philosophy. In this approach items are overhauled after a certain number of flights, flight hours, or landings. It is still used on older aircraft, and for items whose failure would have disastrous consequences for the flight. Such major safety items are lifed at a small fraction of their expected failure times.

G4.2 On-Condition Philosophy

The on-condition philosophy was developed when it was discovered that for many items there was no optimum overhaul time; the reliability of the component was not improved by overhaul of the nonfailed component. So the item is maintained and overhauled as its condition warrants and not at a specified time. The method by which on-condition items are controlled is termed condition monitoring (it can also be applied to hard-life items). It is easiest to apply the on-condition philosophy to those components which can be inspected and maintained in-situ.

It has the following advantages:

1. It allows the appropriate life to be applied to an item according to the actual behaviour of that item in a given operation.

2. A component is removed only if an inspection or functional check reveals a need for removal.

3. It becomes a permanent, partially automatic procedure when the appropriate life for a component has been established by the development program.

As the condition-monitoring approach implies, on-condition does not mean fly-'til-failure. It means fly-'til-the-condition-warrants-change; this may mean immediate change, change at the next check, or change at the next major overhaul. Whether it is a complete change or just in-situ maintenance depends only on the item and its condition.

The on-condition philosophy is best when high aircraft utilization is required because maintenance is done when the aircraft would not otherwise be scheduled. High utilization is most necessary with new, undepreciated equipment to justify the investment. The on-condition maintenance programs are, therefore, best for third-level airlines. In fact, third-level aircraft manufacturers have begun setting up maintenance programs embodying the on-condition philosophy. The Swearingen Metro II uses this approach, but the older Mohawk 298 airframe does not. The resulting reduction of unnecessary overhauls reduces the Metro's cost of maintenance.

G5. Product Support

G5.1 Problems with Support

There are some basic problems in product support:

1. The manufacturer cannot analyze and cater support to the individual operator.

2. Past problems occur in new designs.

3. Production changes affect component interchangeability.

4. Government and manufacturer service bulletins do not take into account accessibility or in-service hardware.

5. Subcontractors do not adequately accept the responsibility of product support.

6. The manufacturer tends to forget the six keys to maintainability as the design progresses--simple, proven, practical, accessible, inexpensive and supported.[85]

G5.2 The Manufacturer's Role

The airframe and engine manufacturers can do much towards easing the operator's maintenance problems by giving good product support.

A manufacturer's guarantee can come in many forms.[86]

1. Standard warranty

2. Ultimate life warranty

3. Reliability guarantees

4. Maximum parts cost guarantees

5. Rewarranty of a supplier's repaired or overhauled equipment

6. Maintenance support contracts--no aircraft on the ground more than 48 hours, etc

7. Buy-back guarantees on spares

8. Delivery time guarantees

9. Specific provisions for loan, lease, and hire of insurance items

The basis of commitments should be guaranteed Mean-Time-Between-Failure (MTBF), Mean-Time-Between-Maintenance-Action (MTBMA), and maintenance costs per flight hour or flight cycle.

The manufacturer should also provide the following information:[86]

1. Adequate data for material planning and initial provisioning, including that from subcontractors

2. Recommendations regarding the acquisition of any facilities, rigs, fixtures, test equipment, or tools

3. Actions necessary for the implementation of Electronic Data Processing (EDP) control

4. Data necessary to establish stock holdings and usage including datum points for measurement of performance, e.g., reliability, usage rates, built-in redundancy, material costs, applicability, etc., including the methods of calculation

5. Availability of parts for lease, hire, and subsequent purchase, and the terms of same

6. Illustrated parts catalogs, maintenance, repair, and overhaul manuals, planning guides, NonDestructive Testing (NDT) manuals, Quick Engine Change (QEC) lists, Minimum Equipment Lists (MEL), and transport data such as size and weight

7. The degree of vendor support required, where it may be obtained, and any relevant agreements

8. Any other information necessary to planning the project budget or operation

G6. Spares

There are two methods of classifying spares. The first of these is a general classification on where the spare is geographically utilized.

1. Line maintenance item--spare replacement and maintenance is done on aircraft.

2. Shop maintenance item--maintenance is done in shop.

3. Overhaul item--maintenance is usually done in the shop or with the whole aircraft in shop.

4. Outstation item--line maintenance item or item that can be installed at outstations.

The second method of classification depends on the utilization and reclaimability of the item. There are three major groups: rotables, recoverables, and expendables.[86]

Rotables include the following:

1. Fully rotable--an expensive component which can be overhauled an unlimited number of times; often a hard-life item. Each unit has a serial number and detailed records are kept to control the location and use of the unit. A working float is required.

2. Repairables--an item capable of a limited number of repairs. Normally moderately expensive ($\geq$\$20), it may have a serial number and special records. A working float and backing stock are required.

Recoverables are those components which may be repaired to a serviceable condition one or more times before scrapping by an operation such as patching, welding, recharging, refilling, etc. Backing stocks are required.

Expendables are items normally scrapped on removal and, as such, require a backing stock. Also called consumables, they are normally divided into expensive items requiring requisition control and inexpensive items with free issue (except for bulk transfers). The groups of expendables include the following:

1. Mandatory (100%) replacement items are discarded and replaced at each assembly pursuant to specification and/or procedure.

2. On-condition replacement items are replaced or continued on the basis of inspection. (Some reclamation may be possible through refurbishment or adjustment.)

3. Miscellaneous hardware items are removed or disturbed during assembly, maintenance, or overhaul. (There is limited reclamation available through outside agencies.)

4. Bulk materials are used in random quantities during the maintenance process.

A fourth group is insurance items which can be rotable, recoverable, or expendable. They are held as a precaution against serious delays and no routine use is planned. They are often held by the manufacturer or by pooling agreements with other airlines. The best situation for the operator is when the manufacturer's capital is tied up in these items and they constitute the largest possible portion of the spares holding.[86]

G7. Component Rework Policy

Rotable spares are determined during aircraft purchase and establishment of the maintenance system. The third-level airline can make important inroads into costs in this area.

The first issued to be decided is which components to overhaul in-house. An airline normally attempts to overhaul those items which are high cost, high turnover, least complex, utilize minimum power, require minimum manpower (particularly specialized manpower), require minimum shop area, and only require cheap and accessible materials--it can be forced to overhaul other items when no other method is available.

Special processes are routinely done by outside shops. These include special cleaning, plating, heat treating, machining of special parts or tools, upholstery, safety equipment, instruments requiring clinically clean shops, and NDT.[43]

APPENDIX H

SHOP EQUIPMENT AND AVIONICS REPAIR COSTS

This appendix contains the cost of maintenance equipment and develops the cost of avionics repair in tabular form. The tables are: Metro Special Tools, Table H-1; Airframe and Engine Shop Equipment, Table H-2; Avionics Test and Office Equipment, Table H-3; and Avionics Repair Costs, Table H-4.

TABLE H-1

METRO SPECIAL TOOLS

Quantity	Item	Price ($)
2	Hydraulic Test Cart	7644
2	Engine Sling	622
1	Test Set--Fuel Quantity	2074
1	Trim Gauge	387
1	Travel Gauge--Rudder	268
1	Travel Gauge--Stabilizer	548
1	Travel Gauge--Aileron	436
3	Tow Bars	2976
2	Test Sets--Voltage Regulator	3900
1	TIT System Tester	2100
1	Calibrator--SAS	400
1	Test Set--Pressure Gauge System	850
1	Test Set--Torque Gauge	150
2	Nicad Battery Chargers	4500
1	Test Set--Steering Amplifier	+ 950

		$27805

TABLE H-2

AIRFRAME AND ENGINE SHOP EQUIPMENT

QUANTITY	ITEM	PRICE* ($)
1	Stocking Truck	3600
3	Ground Power Units	12000
1	Drill Press	350
1	Sheet Metal Cutter	100
2	Compressed Air Units	2000
1	Arc Welder	550
2	Bench Grinders	450
1	Band Saw	300
1	Press	250
3	Tow Tractors	12000
20	Vices	750
6	Personnel Stands (High and Low)	1200
	Assorted Air Tools	2500[1]
1	Wheel Stripper	1250
2	Jack Sets	8950
12	Fire Extinguishers	450
1	Alcoprobe	2500
2	Industrial Vacuums	200
20	Personal Work Stands	950
2	Shearers	200
4	Wheel Trucks	300
50	Work Plans	250
1	A/C Wash Rack	500[1]
8	Units Mobile Shelving (12' x 6' x 3')	6000
4	Nut, Bolt, and Rivet Cabinet	850
1	Bonded Stores Cabinet	250
3	Heavy Duty Work Benches	1050
1	Olympus Boroscope	1200
	Chocks and Ramps	100[1]
8	Waste Bins	250
25	Clothes Lockers	600
1	Lathe	2100
4	Managers Desks and Chairs	1300
2	Secretaries Desks and Chairs	900
1	Visible Card Unit	100
2	Executive Filing Cabinets	200
3	Filing Cabinets	900
2	Typewriters	+ 1250

		$68950
	Miscellaneous (+5%)	3440
	Engine Equipment (only $6206 with RPHC)	+ 54136

	TOTAL	$126526

* Nearest $50

1 Estimated

TABLE H-3

AVIONICS TEST AND OFFICE EQUIPMENT

SHOP TEST EQUIPMENT

ITEM	PRICE ($)
CONTROL PANELS & TEST HARNESSES	
Communication (VHF)	
Linaire LT-5	295
LT-6014	85
Navigation (VHF)	
Linaire LV-5	450
LV-6024	125
Distance Measuring Equipment	
Linaire LD-4	380
LD-8009	90
Transponder	
Linaire LX-3B	425
LX-9001	80
Glide Slope	
Linaire LG-4	360
LG-6016	60
Marker Beacon	
Linaire LM-3	275
LM-4106	50
Radar	
Linaire LW-3	599
LW-7008	187
POWER SUPPLIES	
DC W/Regulated Output - Harrison Lab Model 809A	700
26V @ 400 hz - A/C Static Inverter	1373
TEST SETS	
Automatic Direction Finder	
Collins 970G-1	1200
Collins 970W-1	900
Collins 614L-11/12/13	560
Collins 332C-10	1995

TABLE H-3
(cont'd)

AVIONICS TEST AND OFFICE EQUIPMENT

SHOP TEST EQUIPMENT

ITEM	PRICE ($)
Radio Magnetic indicator	
Collins 332-C1D	1410
Collins 699Z-1	405
Distance Measuring Equipment & Transponder	
IFR ATC 1200 Y3	6750
Collins 339F-12	1180
VHF-UHF	
IFR NAV 750	7000
Radar	
IFR RD 300	9950
METERS	
Multirange	100*
RF Voltmeter	
HP-3406A	495
Digital Voltmeter	
HP-3465A	495
Valve Voltmeter	
HP-410C	950
Transmitter Power Output Meter	
Bird Thruline Model 43	400
Audio Power Meter	
Marconi TF 893A	395
Modulation Meter	
TF 2300 B	1860
Voltage Phase Meter	
HP-8405A	3750
HP-11570A	365
Frequency Counters	
HP-5300B	460
HP-5304A	900
HP-5305B	385

TABLE H-3
(cont'd)

AVIONICS TEST AND OFFICE EQUIPMENT

SHOP TEST EQUIPMENT

ITEM	PRICE ($)	
MISCELLANEOUS		
1 mhz to 512 mhz Signal Generator HP-8640B	6600	
1 hz to 1 mhz Audio Oscillator HGP-200CD	600	
RF Load Bird Thermaline 31B-50	100	
1000 V Insulation Tester	50*	
Bonding Tester	100*	
Dual Trace Oscilloscope HP-1740A	2095	
T-Attenuator General Radio GR 874GA	50*	
6db Pad Measurements Corp. 80ZH3	50*	
Capacitance Bridge General Radio 1617A	100*	
L-Band Detector HP-8482A	+ 180	

TOTAL SHOP ELECTRONIC EQUIPMENT		$58469

AVIONICS OFFICE EQUIPMENT*

Benches (7)	900
Filing & Storage Cabinets (2)	650
Shop Chairs (7)	350
Desk (1)	300
Desk Chair (1)	+ 100

TABLE H-3
(concl'd)

AVIONICS TEST AND OFFICE EQUIPMENT

ITEM	PRICE ($)		
TOTAL OFFICE EQUIPMENT		+ $2300	
AVIONICS SHOP COST			$60769
RAMP TEST SETS**			
Communications & Navigation (VOR. LOC, GS, MKR) IFR NAV-401L	5995		
Distance Measuring Equipment of Transponder IFR ATC-600A	+ 3400		
TOTAL RAMP ELECTRONIC EQUIPMENT			+ $9395
TOTAL			$70164

* Estimated
** Purchased With or Without Avionics Shop

TABLE H-4

AVIONICS REPAIR COSTS

Item	Item Identifier	Number Per Aircraft	Float/1000 Hours(18-Day Turnaround)	Mean Time To Repair (Hours)	Shop Rate ($/Hour)	Labor Cost/ Thousand Hours ($)
Comm.	VHF-20A	2	0.69	4.2	23	66.65
Comm. Tun.	313N-5A	3	0.60	3.7	23	51.06
Nav.	VIR-30A	2	1.33	4.4	23	134.60
Nav. Tun.	313N-4B	2	0.40	3.7	23	34.04
RMI	332C-10	2	0.80	4.1	23	75.44
Slav. Amp.	328A-3G	1	0.25	3.9	23	22.43
Flux. Detect.	323A-11	1	0.08	2.6	23	4.78
ADF	ADF-60B	1	0.28	3.2	23	20.61
ADF Tun.	614L-11	1	0.10	3.2	23	7.36
DME	DME-40	1	0.72	6.2	23	102.67
DME Ind.	339F-12	2	0.34	3.7	23	28.93
XPDR	TDR-90	1	0.35	2.8	23	22.54
XPDR Tun.	613L-3	1	0.10	2.8	23	6.44
Audio Amp.	356F-3	1	0.10	2.8	23	6.44
Audio Con.	913Y-1	1	0.08	2.6	23	4.78
HSI	332E-4	2	1.60	9.9	23	364.32
Rad. Alt.	ALT-55A	1	0.33	4.7	23	35.67
Rad.Alt.Ind.	339H-4	2	0.30	4.0	23	27.60
Rad. Ind.	WXR-250	1	0.27	7.5	23	46.57
Rad. R/T	WXR-250	1	0.43	8.5	23	84.07
Rad. Ant.	WXR-250	1	0.17	4.5	23	17.59
Rad. Gyro	332D-11A	1	1.00	9.9	23	227.70
Total Avionics Cost Per Thousand Hours						$1392.29

TABLE H-4
(concl'd)

AVIONICS REPAIR COSTS

Avionics Cost Per Hour: $\dfrac{\$1392.29}{1000 \text{ X } 0.75} = \$1.8564$

where 0.75 is the labor to total-cost ratio.

Hours Of Labor Per Flight Hour: $\dfrac{\$1392.29}{\$23 \text{ X } 1000} = 0.06054$

Mean-Time-Between-Failures (MTBF): $\dfrac{1000}{\text{Float / 1000 Hours}} = 96.9$ Hours

Mean-Time-To-Repair (MTTR): $\dfrac{\$1392.29 \text{ X } 96.9}{23 \text{ X } 1000} = 5.866$ Hours

Failure-Rate:(1/MTBF) = 0.01032 per Hour

Time To Remove And Replace = 0.5 Hours Or 8.5% of Labor Time
(estimated)

APPENDIX I

THE AFFORDABLE RISK FORMULA

Variables

C = Annual fixed cost of ownership of an item, e.g., aircraft, engine.

V = Annual variable cost of a fully utilized item.

R = Annual revenue produced by a fully utilized item.

I = Annual intangible opportunity loss from unsatisfied demand per item.

P = (R-V) = Annual sales revenue minus variable costs per item.

S = (R-V-C-I) = P-C-I = Annual shortage cost of an item.

n = Number of items installed.

x = Demand in units of capacity, i.e., number of items.

f(x) = Probability density function of capacity demand.

$F(x) = \int_0^{\nu} f(x)\,dx$ = Cumulative distribution of capacity demand.

R(n) = Total expected profit with n items.

AR = 1 - F(x) = Affordable Risk

Derivation

There are two cases:

Case 1: If $x \geq n$ (demand exceeds supply), then profit is $n(P - C) - S(x - n)$.

Case 2: If $x \leq n$ (supply exceeds demand), then profit is $xP - nC$.

Taking account of both cases:

$$R(n) = \int_0^n (xP - nC)f(x)dx + \int_n^\infty n(P - C) - S(x - n) \quad f(x)dx$$

$$\text{"} = P\int_0^n xf(x)dx - nC\int_0^n f(x)dx + n(P - C + S)\int_n^\infty f(x)dx$$

$$- \; S\int_n^\infty xf(x)dx$$

APPENDIX I
(cont'd)

THE AFFORDABLE RISK FORMULA

Substituting

$$F(x) = \xi = \int_0^{\infty} xf(x)dx = \int_0^{n} xf(x)dx + \int_n^{\infty} xf(x)dx$$

or

$$\xi - \int_0^{n} f(x)dx = \int_n^{\infty} xf(x)dx$$

Then:

$$R(n) = (P + S)\int_0^{n} xf(x)dx - n(P + S)F(x) + n(P - C + S) - S$$

Differentiating with respect to n and setting equal to zero:

$$\frac{dR(n)}{dn} = (P + S)nf(n) - (P + S)nf(n) - (P + S)F(x) + (P - C + S)$$

$$\text{"} \quad = - (P + S)\ F(x) + P - C + S$$

Then:

$$(P + S)\ F(x) = (P + S) - C$$

$$F(x) = 1 - C/(P + S)$$

Converting to the complementary cumulative curve of F(x):

$$AR = 1 - F(x)$$

Therefore,

$$AR = C/(P + S)$$

Unfortunately the cost of undercapacity, S, is partially a matter of judgment as the intangible opportunity loss, I, is indeed intangible. Being optimistic, I is set to zero and S becomes

$$S = P - C$$

and the formula for affordable risk:

$$AR = \frac{C}{(2P-C)}$$

APPENDIX I
(concl'd)

THE AFFORDABLE RISK FORMULA

On the proposed airline system, each route requires exclusive use of one aircraft (based on annual utilization, U_1). Optimizing the contribution of a route requires that the cost of one aircraft be allocated it. Therefore, contribution is equal to

$$Con = R - V - C = P - C$$

and

$$P = Con + C$$

so that affordable risk formula becomes

$$AR = \frac{C}{(2(Con + C) - C)} = \frac{C}{2(Con) + C}$$

APPENDIX J

SENSITIVITY ANALYSIS

Sensitivity analysis is used to determine the relative effects of variables on the outputs of the model. Once determined, variables to which the model is sensitive should be defined as probability distributions and variables to which the model is insensitive may be input as most-likely values.

The technique of sensitivity analysis is simply to hold all variables at their most-likely values except the variable whose effects are to be determined. It is important that estimates of the effects of different variables be at the same level, e.g., all variables may be compared at the 5% level, that level which they will only exceed 5% of the time. If the distribution of the variable is skewed, it is necessary to analyze each tail.

The technique is not precise because it ignores dependencies between variables. If the model is nonlinear, sensitivity analysis can be dangerous as effects may be correlated. Suppose a firm only expands if both A and B occur. One variable, x, only effects A so the firm does not expand and the solutions appear insensitive to x. One variable, y, only effects B so the firm does not expand and the solutions appear insensitive to y. But if both x and y could occur simultaneously then A and B would both occur and the firm could expand. Sensitivity analysis does not vary them simultaneously (at least not at the first (uncorrelated) level). This example is a nonlinear model for which traditional sensitivity analysis is inappropriate.[23]

The sensitivity of the model may be a function of the output required. If the net-present-value of a long-lifed project is required, down payment requirements may have little effect on the results, but if the cash required to start up is required, down payment requirements may be extemely important. Conversely, growth rate of the firm may not effect down payment requirements, but it will effect net-present-value.

The airline model considered in the analysis was sufficiently small that most variables could be handled as probability distributions. It had significant dependencies in the cost-revenue area, and both net-present-value and the ability to analyze start-up cash were required. The author had already constructed a similar model[87] and determined the sensitive variables, which were handled explicitly from the beginning in this model, so no further sensitivity analysis was done.